Iron and Steel Engineer

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J. F. KELLY, *Editor*

CONTENTS

Volume VIII | JULY, 1931 | Number VII

A. I. & S. E. E. CLEVELAND CONVENTION COMMENTS 313

DETERMINATIONS OF TIME REQUIRED FOR THE HEATING OF STEEL—By T. J. Ess, Combustion Engineer, Republic Steel Corporation, Massillon, Ohio 317

SPOILAGE OF MATERIAL DUE TO GREASE DRIPPAGE FROM OVERHEAD TRAVELING CRANES—By T. J. Flaherty, Electrical Superintendent, American Rolling Mill Co., Ashland, Ky. 321

ELECTRICAL EQUIPMENT OF THE SLABBING AND HOT STRIP MILLS AT THE WHEELING STEEL CORPORATION'S STEUBENVILLE PLANT—By James Farrington, Electrical Superintendent, Wheeling Steel Corp., Steubenville, Ohio and H. A. Winne, Industrial Engineering Department, General Electric Co., Schenectady, N. Y. 323

COPPER ALLOY WELDING RODS—By I. T.Hook, Research Engineer, The American Brass Company, Waterbury, Conn. 337

ITEMS OF INTEREST 341

LIST OF EXHIBITORS, A. I. & S. E. E., IRON & STEEL EXPOSITION 346

JIM'S PAGE 347

QUESTIONNAIRE IN CONNECTION WITH A SPECIAL STUDY REGARDING OPERATION IN THE STEEL INDUSTRY OF ANTI-FRICTION BEARING EQUIPPED MILL TYPE MOTORS II

QUESTIONNAIRE FOR BEARING MANUFACTURERS. SPECIAL STUDY REGARDING OPERATION OF ANTI-FRICTION BEARING EQUIPPED MILL MOTORS III

ADVERTISERS INDEX IV

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Questionnaire In Connection With A Special Study

REGARDING

Operation In The Steel Industry of Anti-Friction Bearing Equipped Mill Type Motors

BY

SPECIAL COMMITTEE ON BEARINGS
ASSOCIATION OF IRON & STEEL ELECTRICAL ENGINEERS
1010 EMPIRE BUILDING — PITTSBURGH, PA.

The Special Committee on Bearings of the Association of Iron & Steel Electrical Engineers is making a special study regarding the Operation of Anti-Friction Bearing Equipped Mill Type Motors. The data and information secured will be tabulated and distributed to the Engineers of the Iron & Steel Industry.

1. Are Anti-Friction Bearings, as now applied on Mill Type Motors, giving satisfaction?

2a. How many Mill Type Motors equipped with Anti-Friction Bearings operating in your Plant? How many of these motors operate at speeds in excess of 700 R. P. M.?

2b. If you do not wish to answer 2a.—
What percentage of Mill Type Motors equipped with Anti-Friction Bearings are operating in your plant? What percentage of these motors operate at speeds in excess of 700 R. P. M.?

3. What maximum total temperature or temperature rise above surrounding air have you experienced on Anti-Friction Bearings as measured by thermometer inserted through grease hole for admitting grease to bearing for motors operating at speeds greater than 700 R. P. M.?

4. Give motor frame, R. P. M., size and make of bearing and lubricant used in bearing on which temperature was measured.

5. Were there any conditions present which imposed end thrust on bearing being tested? Was end thrust continuous and in one direction?

6. What percentage of Anti-Friction Bearing equipped Mill Motors operating in your Plant which must take continuous end thrust?

7. Is this end thrust caused by axial inclination of the motor, by helical gears, by worm gearing, or other causes?

8. Are any of your Mill Motors operating under continuous end thrust conditions equipped with supplementary thrust bearings?

Please send your replies to

F. D. EGAN, *Chairman,*
Special Committee on Bearings
Association of Iron & Steel Electrical Engineers
1010 EMPIRE BUILDING
PITTSBURGH, PA.

Questionnaire for Bearing Manufacturers

Special Study Regarding Operation of Anti-Friction Bearing Equipped Mill Motors

BY

Special Committee on Bearings
Association of Iron & Steel Electrical Engineers
1010 Empire Building — Pittsburgh, Pa.

The Special Committee on Bearings of the Association of Iron & Steel Electrical Engineers kindly asks the Anti-Friction Bearing Manufacturers of the United States to furnish their data and information in connection with the above questions.

This information and data will be tabulated and distributed to the engineers of the Iron & Steel Industry in THE IRON & STEEL ENGINEER, the Society's official publication.

1. What are your limiting operating speeds for Anti-Friction bearings applied on Mill Motors as tabulated in the June, 1930, issue of Iron & Steel Engineer when lubricated with grease?
2. What further increase in speed is allowable if change is made to oil lubrication?
3. In determining the maximum speed limit for grease lubrication, do you wish to specify any particular grade or consistency of grease?
4. Will this recommendation be altered for motors which operate on outdoor locations and where surrounding temperature varies over a wide range from summer to winter conditions?
5. Is the maximum operating temperature set by considerations of safety of the bearing material or to avoid break down of grease with subsequent injury to bearings?
6. Do you recommend your bearings for sustaining axial thrust arising from axial inclination of motor, helical gearing, etc., without the introduction of supplementary thrust bearings?
7. If a supplementary thrust bearing is required, what type of bearing do you recommend for continuous thrust in one direction?
8. Do you consider thrust imposed on bearing from armature seeking Electrical neutral to be sufficient to require special bearing for thrust?

Please address your replies to

F. D. EGAN, *Chairman*
Special Committee on Bearings
Association of Iron & Steel Electrical Engineers
1010 EMPIRE BUILDING
PITTSBURGH, PA.

INDEX TO ADVERTISERS

A

Alliance Machine Co. 389
Allis Chalmers Manufacturing Co. 400
Aluminum Company of America 374-75

B

Baker Raulang Company 363
Bantam Ball Bearing Co. 382
Bartlett Hayward Company 398
E. W. Bliss Co. 359
Brown Instrument Company 354

C

Century Electric Company 357
Clark Controller Co. 352
Cleveland Crane & Engineering Co. 365-66
Combustion Engineering Corporation 358
Crocker Wheeler Electric Mfg. Co. 360
Crouse Hinds Company 368

D

DeLaval Steam Turbine Co. 353
Doubleday Hill Electric Co. 391

E

Electric Controller & Mfg. Co. 371-399
Electric Machinery Mfg. Co. 379
Electrical Engineers Equipment Co. 388
Electro Dynamic Company 396
Elliott Company 349
Erie Steel Construction Company 392
Erie Malleable Iron Company 370

F

Farrel-Birmingham Co., Inc. 376

G

General Electric Co. 364 Cover 4

H

Hyatt Roller Bearing Company 362

I

ITE Circuit Breaker Co. Cover 3

J

Jefferson Electric Company 385

K

Keystone Lubricating Company 355

L

LeCarbone Co. 391

M

Mantle Engineering Co. 350
Martindale Electric Co. 397
Moloney Electric Company 393
Morgan Construction Company 381
Morgan Engineering Company 351
Morganite Brush Co., Inc. 392

N

National Carbon Company, Inc. 356
New Departure Mfg. Company 377
Nichols Lintern Company 402
Norma Hoffmann Bearings Corpn. 367

O

Ohio Electric Mfg. Co. 395
Okonite Company 378

P

Pennsylvania Transformer Company 394
Pyle National Company 380

R

Railway and Industrial Engineering Co. 394
Reliance Electric & Engineering Co. 387
Rockbestos Products Corporation 390
Rowan Controller Co. 361

S

Shepard Niles Crane & Hoist Corp. 401
SKF Industries, Inc. 386
Stackpole Carbon Company 383
Stimple & Ward Co., Inc. 389
Sundh Electric Co. 352
Surface Combustion Corp. 350-373

T

Thompson Electric Co. 388
Timken Roller Bearing Co. Cover 1
Tool Steel Gear & Pinion Co. 384

U

Union Carbide and Carbon Corp. 356
United States Graphite Company 393
R. E. Uptegraff Mfg. Co. 390

W

Wellman Engineering Co. 372
Westinghouse Electric & Mfg. Co. Cover 2
Weston Electrical Instrument Corp. 369

FIG. 1.—General view of Iron & Steel Exposition.

A. I. & S. E. E.
Cleveland Convention Comments

The 27th Convention and Iron and Steel Exposition of the Association of Iron and Steel Electrical Engineers held in Cleveland, Ohio, June 15th to 19th, was one of the most successful in the history of the Association. Starting with the business session on Monday morning and ending with the inspection trip of the U. S. S. Akron on Friday afternoon, every activity was well attended and tremendous interest shown. The aisles of the Iron and Steel Exposition were filled with interested engineers inspecting the new developments offered by the equipment manufacturers.

The keynote of the Convention and Exposition "Produce Steel More Economically" was reflected by the engineers who visited each exhibitor. Each piece of equipment and material was inspected and examined with this thought always in mind.

Over 9,000 persons registered at the official registration desk of the Association. 2,500 Weekly Membership and Exhibitor Passes were issued during the week. 800 persons attended the informal reception on Monday evening; 1200 persons attended the boat ride on Tuesday evening; 600 persons attended the formal reception, dance and concert on Thursday evening and 350 persons attended the inspection trip of the Goodyear Tire and Rubber Company's Power Plants and the U. S. S. Akron and Docks.

Technical Sessions

The technical sessions were well attended. The registration at these sessions totaled 1,572 persons. The number of papers presented was 40. The papers that were not printed in advance will appear with the discussions in later issues of THE IRON & STEEL ENGINEER.

"Electrical versus Mechanical Devices Used in Combustion Control of Open Hearth Furnaces" was

one of the outstanding features of the Convention. All of these papers together with the discussion will appear in the September issue of THE IRON & STEEL ENGINEER.

The Lubrication Engineering Division conducted an all day session, which was one of the best attended sessions of the week. Many lubrication problems, connected with the Iron and Steel Industry were discussed. Roll Neck Lubrication was the major issue. Much interest was shown when the announcement was made that a general conference of this Division would discuss Lubricants for Roll Necks at a Fall meeting to be held in October at Pittsburgh.

A new committee will be added to the Lubrication Division, which will be known as The Lubrication and Device Development Committee. The personnel of this Committe will appear in the September issue of THE IRON & STEEL ENGINEER.

The Safety Engineering program was very interesting and timely. It developed a new thought in increasing the welfare and efficiency of the employee through controlled conditions of a plant. These papers will be valuable additions to the Transactions of the Society.

The Special Committee on Bearings presented a valuable report in connnection with Cranes, Motors and Roll Necks. Papers covering Twin Motor and Strip Mill Drives were well received.

Conductors of Heavy Alternating Currents was the subject of an interesting paper and was discussed by a large and interested audience. An addition to the program in the form of a paper "Synchronous Motors" was most ably presented and will appear in an early issue of THE IRON & STEEL ENGINEER.

One noticeable feature in all of the discussions was the trend toward economics, not only whether apparatus operated successfully but also whether it operated at a profit.

FIG. 2.—General view of Iron & Steel Exposition.

Iron and Steel Exposition

Over nine thousand persons registered at the Iron and Steel Exposition. The visitors came from every Steel Mill Center in the United States and Canada. The booths were so arranged that it was possible to see each and every exhibitor in the Exposition. The exhibitors and the visitors all expressed their approval of this new layout and, to the best of our knowledge, and experiences, this new layout was a successful experiment in the handling and conducting an engineering exposition.

The exhibits were varied. They represented the latest developments in electrical, mechanical, lubrication and combustion equipment, applicable to the Iron and Steel Industry. One prominent engineer remarked that it would require three months of his time to visit around the Industry to see what could be seen at the Exposition in two days' time. This remark alone emphasizes the value of the Iron and Steel Exposition.

The exhibitors are to be congratulated on their originality in arranging their displays. Each and every booth was a source of information for Steel Mill Executives and Engineers.

The application engineers, who had charge of the various exhibits, were men with years of experience in the application, design and installation of equipment used in Steel Plants.

The manufacturers are to be congratulated on the type and character of engineers sent to the Exposition to demonstrate their equipment.

Taking everything in consideration, it is safe to write that with the engineers who demonstrated the equipment and the engineers and executives who visited the booths, they represented the Steel Mill Engineering Talent of the United States.

FIG. 3.—General view of Wire Association Exhibits.

Mr. F. O. Schnure, President of the A. I. & S. E. E. reported as follows:

The Association of Iron & Steel Electrical Engineers meet at Cleveland, Ohio, June 15th to 19th, 1931 to discuss the economic problems associated with the operation of Steel Mill Equipment.

At no time, within the last ten years, has the installation, operation and maintenance of Steel Mill Equipment been of such vital interest, both to the producer of Steel and to the manufacturer of Steel Mill Equipment.

Development is, therefore, a paramount thought in all lines of Equipment and the Cleveland Conference of the Engineers of the Iron and Steel Industry will be devoted to the new designs and developments, calculated to encourage a more liberal profit in producing Steel.

Over one hundred and fifty equipment builders will exhibit their latest products in Electrical, Combustion, Lubrication and Mechanical equipment, with one idea—**to produce Steel more economically.**

At the Technical Sessions one whole day will be devoted to Combustion Control of Open Hearth Furnaces; one day to Lubrication of Roll Necks and Machinery; one day to Twin Motor Drives (one of the latest developments in rolling mill drives), also, Cold Strip Mill Drives; one day to promoting the Efficiency and Health of the Employees Through New Developments in Plant Operation. Papers on wire and wire products are also a major part of this program, as well as the Application of Anti-Friction Bearings to All Types of Steel Mill Equipment.

With the rapid development in Steel Equipment, it is claimed that the modern Steel Plant of today will be obsolete in ten years. Claims are being made that one particular electrical development, which will be on exhibit at the Iron and Steel Exposition, will revolutionize the operating practices, beginning with the car dumper and running down to the finishing departments. Every Engineer in the Iron and Steel Industry should see this development.

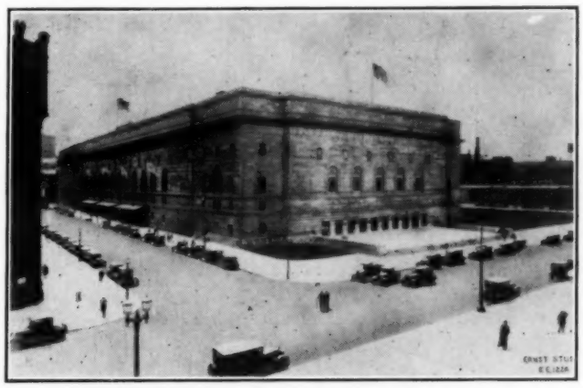

FIG. 4.—Cleveland Public Auditorium.

Realizing that these are critical times, when economy and costs are the uppermost thoughts in every Executive's mind, we believe you could, with profit, attend all the conferences and the Iron & Steel Exposition with results that will be measured in dollars and cents.

A program of all of this week's activities has been placed in your hands. All of the conferences and activities after this morning will be held at the Cleveland Public Auditorium.

Report of the District Sections

The officers of our Birmingham, Chicago, Cleveland, Philadelphia and Pittsburgh Sections are to be congratulated upon the splendid results they obtained during the last year.

The Technical Sessions held during this year were well attended and the subjects presented and discussed were all in connection with the Iron and Steel Industry.

The Inspection Trips, conducted by the various Sections, were highly successful, some of them being attended by as high as 700 Engineers and Executives. Plant Inspection Trips are one of the most valuable auxiliaries that our Society has to offer its membership to see the equipment in operation. The Association is deeply indebted to the Iron and Steel Industry for their liberal attitude in opening their doors so freely to our Society, especially in view of the fact that it requires quite an expenditure on the part of the Steel Plants.

Lubrication Engineering Division

During the past year the Lubrication Engineering Division was organized and our predictions are that this Division will render a most valuable service to the Iron and Steel Industry.

Meetings were held in the various Sections and the attendance reflected the intense interest of the Steel Plants in Lubrication.

The program for the next year's work embraces:

1. The formation of a development committee, whose purposes will be the gathering and distribution of data to the Steel Plants in connection with New Devices, New Practices and Developments in Lubricants.
2. Technical Sessions in all of the District Sections covering the application of lubricants to all types and forms of Steel Mill Machinery.
3. A closer form of cooperation between the manufacturers of lubricants and devices with the Steel Industry.

Standardization—Mill Type Motors

The Association desires to announce that there are now two nationally known electrical manufacturers who are meeting the A. I. & S. E. E. Standards with respect to Mill Type Motors. At this time we believe it is in order to extend to Mr. A. C. Cummins our Association's appreciation for his work in connection with Standardization of Mill Type Motors.

Standardized Symbols for Control Apparatus

The Association is now collecting data and information from the Steel Plants in United States and Canada in connection with control apparatus, with the view of presenting it to the National Electrical Manufacturers Association and cooperating with them in the preparation of Standardized Symbols for

FIG. 5.—General view of Iron & Steel Exposition.

Control Apparatus. Mr. J. J. Booth will present to-day the views of the Iron and Steel Industry in connection with this subject.

It is also the opinion of the Association of Iron & Steel Electrical Engineers that our Standardization Committee should appoint a Sub-Committee to

make a study of standardized drawings to cover the assembling and installation of Combustion Control Apparatus in the field of operation.

Reports of National Committees

The National Committees will report through papers to be presented at this Conference.

The Iron & Steel Engineer

Everybody recognizes today that our medium, THE IRON & STEEL ENGINEER, is rendering a most valuable engineering service to our Industry. This may be attributed to the hearty cooperation of all of our membership in preparing the editorial matter, which appears in the IRON & STEEL ENGINEER each month.

You are cordially asked to continue your efforts to help keep this medium "THE LEADING ENGINEERING PERIODICAL OF THE IRON AND STEEL INDUSTRY."

The Iron & Steel Exposition

One of the objects of an apparatus exhibition such as the Iron & Steel Exposition is to acquaint the public with the status of the art in reference to the various lines of apparatus used in the Industry.

It would require months of your time to investigate and inspect the equipment, apparatus and materials you will be able to see in one day at our Exposition.

National Committees

The President and Board of Directors of the Association of Iron & Steel Electrical Engineers desire at this time to express their sincerest appreciation to the officers and members of the National Committees for their work this year.

Convention Committees

The Association is grateful to all of the Chairmen and members of the various Convention Committees who are helping to make this 27th Convention and Exposition a success.

Membership

Our Membership Committees have functioned very successfully this year and the Association of Iron & Steel Electrical Engineers have admitted to membership 169 new members for the year 1931.

As President of the Association, I desire to extend to the Board of Directors and the Membership my keenest and sincerest appreciation for their splendid cooperation during my incumbency.

ELECTION OF OFFICERS

The Tellers reported the following election of officers for the ensuing year, August 1, 1931 to July 31, 1932:

President: J. J. Booth, Electrical Superintendent, National Tube Company, Gary, Indiana.

First Vice President: J. D. Donovan, Electrical and Mechanical Superintendent, Republic Steel Corporation, Massillon, Ohio.

Second Vice President: W. E. Miller, Electrical Superintendent, Bethlehem Steel Company, Johnstown, Pa.

Treasurer: Walter H. Burr, Electrical Superintendent, Lukens Steel Company, Coatesville, Pa.

Secretary: William Jackson, Electrical Superintendent, Homestead Steel Works, Carnegie Steel Company, Munhall, Pa.

Director at Large: J. H. Van Campen, Chief Engineer of Youngstown District, Republic Steel Corporation, Youngstown, Ohio.

Directors: K. M. Raynor, Electrical Superintendent, Bethlehem Steel Company, Bethlehem, Pa.

G. T. Hollett, Combustion Engineer, Illinois Steel Company, South Chicago, Illinois.

G. R. Carroll, Electrical Superintendent, Jones & Laughlin Steel Corporation, Aliquippa, Pa.

C. C. Pecu, Lubrication Engineer, Bethlehem Steel Company, Lackawanna, N. Y.

B. Thele, Electrical Department, Tennessee Coal Iron & R. R. Company, Fairfield, Ala.

J. F. Hunter, Safety Engineer, Carnegie Steel Company, Pittsburgh, Pa.

J. H. Wagner, Electrical Superintendent, Acme Steel Company, Chicago, Ill.

J. A. Clauss, Chief Engineer, Great Lakes Steel Corporation, Detroit, Mich.

STATEMENT OF POTTER TITLE AND TRUST CO., TRUSTEE FOR ASSOCIATION OF IRON AND STEEL ELECTRICAL ENGINEERS

ASSETS

As of June 12, 1931

Cash			$ 37,501.88
Potter Title and Trust Co., Svg. Acct. 11500		9,020.26	
Liberty Loan Bonds	(Par)	1,000.00	
U. S. Rubber Co. Bonds	(Par)	1,000.00	
Potter Title and Trust Company Mortgages	(Par)	24,700.00	
American Rolling Mills Company Bonds	(Cost)	5,976.00	
American Tel. and Tel. Company Bonds	(Cost)	8,406.00	
B. F. Goodrich Company Bonds	(Cost)	5,385.00	
Tex. Pac.—Mo. Pac. Ter.Rwy Bonds	(Cost)	5,260.00	
Jones & Laughlin Steel Corp. Bonds	(Cost)	4,175.00	
Grand Trunk Railway Bonds	(Cost)	5,235.00	
Youngstown Sheet & Tube Company Bonds	(Cost)	6,011.00	
Pennsylvania Railroad Bonds	(Cost)	6,498.50	
Republic Iron & Steel Company Bonds	(Cost)	4,055.75	
Southern Railroad Company Bonds	(Cost)	4,462.00	
Chesapeake & Ohio Railway Co. Bonds	(Cost)	4,192.00	
Illinois Central R. R. Company Bonds	(Cost)	3,933.50	
Pgh., Cin., Chi. & St. Louis R. R. Bonds	(Cost)	4,053.00	
Standard Oil Co. of New Jersey Bonds	(Cost)	4,182.00	107,545.76
TOTAL ASSETS			$145,047.64

RAY C. BOWMAN,
Trustee's Agent.

Determinations of Time Required For The Heating of Steel

By T. J. ESS*

A problem often encountered in combustion work is that of heat penetration in steel, and, in spite of its vital importance, what little information is available on the subject does not seem to be generally known. It is therefore the purpose of this discussion to assemble and compare various sources of this information, in an attempt towards their correlation.

A survey of the conditions entering into problems concerning the heating of steel shows an array of variables so great as to make each case almost an individual problem. Items which must be considered in these calculations are:

1. Time of heating.
2. Temperature to which stock is to be heated.
3. Furnace temperature.
4. Allowable temperature differential between surface and center of stock.
5. Size of stock.
6. Shape of stock.
7. Condition of stock surface.
8. Conductivity, specific heat and density of stock.
9. Size of furnace.
10. Flame conditions in furnace.

The inter-dependence of these items, and the marked influence of each on the problem is apparent from their following brief consideration.

1. The time of heating naturally depends on all the succeeding items, and as it is usually the answer sought in calculations of this kind, will be considered in connection with the other items.

2. For a given furnace temperature, with all other conditions the same, a higher stock temperature requires a longer heating time. A temperature-time curve shows a rapidly rising curve, flattening out as the stock temperature approaches the furnace temperature as a limit. This curve closely resembles a logarithmic curve, and is, in fact, very closely satisfied at least in the pertinent temperature range by an equation of the form $Y = C\,(e)^{mx}$ where Y represents time, and x stock temperature, while C and m are constants for the given furnace temperature, and e is the logarithmic base, 2.72. In passing through the critical temperature range, these curves are interrupted, but later catch up and follow the original equation. In heating for forging or rolling, the effect of this recalescence is therefore not so important, but in heat treatment, which is usually close to this range, this effect must be taken into consideration. This matter will be again touched on in this discussion.

3. Furnace temperature has a very marked effect on the time required to heat a given piece. The temperature-time curves for a given piece of stock become much steeper as the furnace temperature increases. This is in accord with the laws of heat transmission, which are too well known to justify discussion here. Experimental determinations in the heating of ⅛" skelp have shown the temperature-time curves at various furnace temperatures to follow the equation given in the preceding paragraph, with the following values for the constants, C and m:

Furnace Temp.	C	m
2100°F.	1.75	.002025
2450°F.	2.9	.00135
2680°F.	3.25	.000965

With these values, Y is expressed in minutes and x in degrees F. In using this form of equation, furnace temperature, of course, must be recognized as a limit. Thus, stock can be heated to 2100° in a 2300° furnace much faster than it can be heated to 1600° in an 1800° furnace.

4. The allowable temperature differential between surface and center of stock limits the rate of heating, as this difference in temperature is roughly inversely proportional to the time of heating. The analysis of the stock may not permit rapid heating. The allowable differential is further dependent on the purpose of the heating operation. Accurate heat treatment requires a uniformity of temperature entirely unnecessary in a rolling operation, while drop forging allows an even greater variation. These considerations are purely metallurgical, and must be dictated from this standpoint. It is perhaps needless to say that grave offenses are common on both sides of the proper heating rate.

5. Larger sizes of stock naturally require longer time for the same degree of heating. For a given shape of stock, the time required for the surface temperature to approach closely to the given furnace temperature is almost directly proportional to stock thickness. The thicker the stock, the greater the difference in temperature between surface and center, the differential being approximately proportional to thickness at any given surface temperature. With thick stock, say 4" and over, heat diffusion through the stock is the controlling factor, while thin stock heating depends primarily on heat transfer into the stock surface.

6. The shape of the stock has a marked effect on the heating time required. For example, for equal uniformity in heating, a plate takes almost twice as long as a round or square bar, and almost three times as long as a sphere, where plate thickness, bar diameter and sphere diameter are equal. Heat absorption depends on exposed surface, a given stock volume attaining a certain temperature faster, the greater its surface. Thus, heating time is also dependent on a ratio of stock volume to stock surface.

7. The condition of stock surface may materially change the rate at which heat is transferred into the

* Combustion Engineer, Republic Steel Corporation, Massillon, Ohio.

stock. A highly oxidized surface may closely approach black body characteristics, while a polished surface, as might be produced by some form of cold working, will reflect a greater portion of heat, necessitating a longer heating time.

8. Physical characteristics of the stock must also be considered. Density and specific heat determine the quantity of heat required to raise the stock to the required temperature, while thermal conductivity controls heat penetration. These characteristics are combined to form a factor known as diffusivity, to which heating time is inversely proportional for equal uniformity of heating under given conditions. Diffusivity equals conductivity ÷ (specific heat x density).

9. The size of the furnace in relation to stock size also influences the heating time. The greater the ratio of brick surface to stock surface, the faster will be the heating. This ratio is limited, however, by loss in efficiency due to poor furnace utilization.

10. Flame conditions in the furnace may have a marked effect on heating time. A luminous flame will radiate more heat than a non-luminous one, and will therefore give more rapid heating. A non-luminous flame radiates some heat, but must place greater dependency on transfer by convection. As heat transfer by convection is essentially a film proposition, it is increased by higher velocities and turbulence.

For the determination of heating time, various methods are available. Perhaps the most commonly used rules are those given by Trinks, "Industrial Furnaces," volume 1, pp 36-37, which are:

1. Heat penetrates at the rate of ⅛ inch in five minutes.
2. Forging ingots are heated at the rate of twenty minutes per inch of diameter, if of low carbon steel, and at the rate of thirty to thirty-five minutes per inch of diameter if of high carbon or alloy steel.
3. Steel can be heated in a furnace at a rate of 30 pounds per square foot of hearth area an hour for heat treating; 60 pounds per square foot an hour for annealing; 80 pounds per square foot an hour for uniform temperature forging and rolling; and 110-130 pounds per square foot an hour for work in which 40-50° F. temperature difference per inch of thickness stock is allowable.
4. Steel bars for drop-forge work can be heated at the rate of eight to ten minutes per inch of diameter.

Mawhinney, "Practical Industrial Furnace Design," p. 78, qualifies rules 1 and 2 for temperatures of 1400° F. and over, doubling the time for temperatures 800°-1400° and tripling it for temperatures under 800°. That there should be some qualification to these rules is apparent from the following figures, based on a 20″ ingot, heating the center of the ingot to 200° under furnace temperature:

Furnace Temp.	Temp. of Ingot Center	Time Hours	Minutes Per Inch of Diameter	Minutes Per ⅛ Inch
1400	1200	7.5	22.5	5.6
1800	1600	6.5	19.5	4.9
2400	2200	4.8	14.4	3.6
2600	2400	4.3	12.9	3.3

However, in the usual hot-working temperature ranges, the rules are sufficiently close for most purposes.

H. Freund, "Maschinenbau," (abstracted in "Fuels and Furnaces," August, 1928), has developed a method and chart for the determination of time required to heat up forgings of various sizes to different temperatures. These calculations are based on the ratio of stock volume to stock surface, in an equation:

$$t = a \frac{V^m}{O^n}$$

where t = time, V = stock volume, O = stock surface, a and the exponents m and n are constants which were determined by actual test. These constants as given in the article referred to cannot be safely used without further knowledge of prevailing conditions, but the discussion presents a method for constructing a chart for use with forge furnaces and similar heating operations.

Results of actual tests on small sized bars were published in Ryan-Scully's "Industrial Heat Review," September, 1930. Center temperature of the stock was determined from actual thermocouple readings. Tests were conducted in an electric furnace. Results are as follows:

Furnace Temp. (Approx.)	Temp at Center of Stock	Size of Stock				
		1″	2″	3″	5″	7″
1200	1000	.....	58	78	139	.....
1400	1200	11	28	45	66	90
1600	1400	25	42	61	85	110
1800	1600	10	27	42	59	85
2000	1800	7.5	15.5	29	47	71
		Heating Time in Minutes				

These results show clearly the effects of the point of recalescence, or critical temperature range, upon heating of steel. It is hazardous, however, to use figures obtained under special conditions which may be vastly different from conditions found in practice.

Perhaps the most thorough analytical investigations on the subject are those of Heinrich Grober, "Zeitschrift des Vereines Deutscher Ingenieure," May 23, 1925 (abstracted in Trinks "Industrial Furnaces" volume 1, 2nd edition pp. 312-320, and in "Fuels and Furnaces," August, 1925) and of Gurney and Lurie, "Journal Ind. Eng. Chem.", 1923 (abstracted in Trinks, as above, and in Haslam and Russell, "Fuels and their Combustion"). Except for the form of the curves presented, these methods are very similar, using the same values and ratios, most of which can be obtained in handbooks. Only one item, the co-efficient of heat transfer, requires judicious selection, according to prevailing conditions. Space does not permit an extended explanation of these methods, and the above references are readily available. However, it should be noted that these methods do not take into account the effect of recalescence, and are therefore not correct when dealing with temperatures within, or very near, the critical range. Above this, however, as in rolling or forging, the curves are very close. They also give both surface and center temperatures of the stock, thus assisting in determining time required for the degree of temperature uniformity desired.

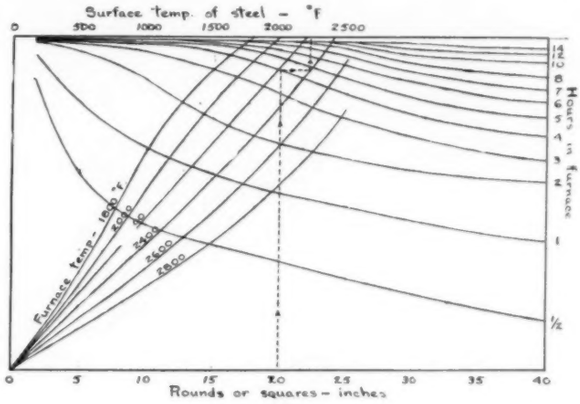

FIG. 1.

E. I. Janitzky, "Trans. A.S.S.T.", February and November, 1924, (abstracted in Trinks "Industrial Furnaces," volume 1, 2nd edition, pp. 327-329) develops an empirical formula from data taken on a small bar. This formula is based on a rather even temperature distribution in the stock, with furnace temperature but slightly higher than the final stock temperature. The effect of recalescence is taken into consideration, which makes this method of particular value in dealing with temperatures near the critical range. No account is taken in this method of proportionate size of furnace and stock (experimental work done with ratio of furnace surface to stock surface of about 6), or of flame condtions.

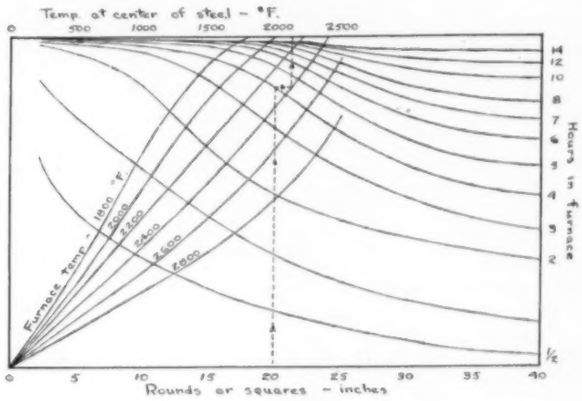

FIG. 2.

By way of comparison of the foregoing rules, let us take examples, of various sizes and shapes, to be heated to various temperatures at the center of the bar. The following tabulation shows the heating times thus obtained:

Method	Heating Time—Hours								
	6" Dia. Bar			20" Dia. Ingot			6" Slab		
	2200°	1800°	1400°	2200°	1800°	1400°	2200°	1800°	1400°
Trinks, Rule 1	2	2	2	6.7	6.7	6.7	2	2	2
Trinks, Rule 2	2	2	2	6.7	6.7	6.7	.....	.....	.....
Grober Gurney & Lurie	1.7	2.1	2.9	3.9	4.8	5.9	2.3	2.7	2.9
Janitzkey	1.75	2.15	3.4	5.9	7.	11.	3.5	4.3	6.8
R. S. "Ind. Heat"	.....	1	1.6	.....	.....	.....	.....	.....	.....

Great discrepancies are at once apparent in these results, due principally to the following reasons; Trinks' rules do not consider the effect of stock shape, or of the higher rate of heat transmission obtained at higher temperatures; Grober and Gurney and Lurie do not consider the effect of recalescence; Janitzky

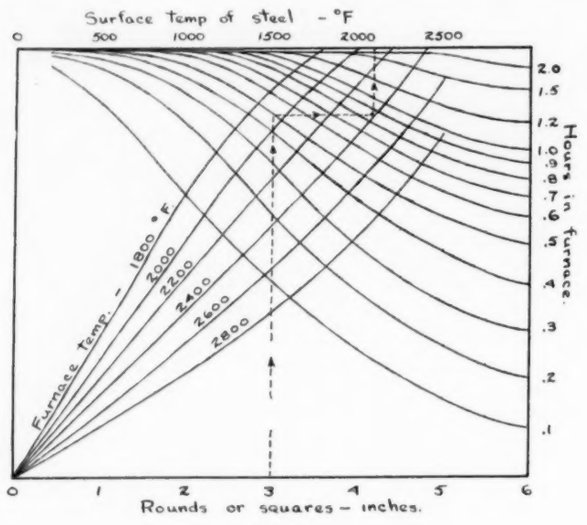

FIG. 3.

presumes a uniformity of heating not approached by the other methods, with stock temperature more closely approximating furnace temperature. Figures from R. S. "Industrial Heat Review" are considerably lower than those of the other references, probably due to unusual test conditions.

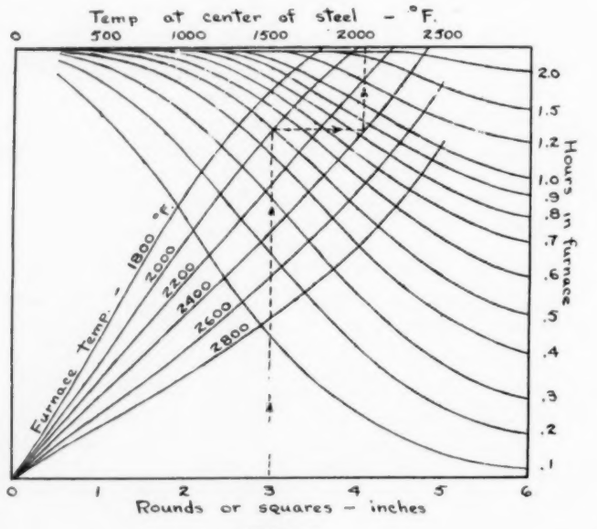

FIG. 4.

In selecting a method to use, then, it becomes evident that each method has its own definite field of application. The rules given by Trinks serve well for rough approximations, for which they are really meant, and if qualified by a factor for temperature and stock shape, will give fairly accurate results. The methods of Grober, and of Gurney and Lurie, are applicable to heating for ordinary forging and rolling, where temperatures are well above the critical range, while Janitzky's method seems best for heat treating, or other comparatively low temperature work requiring uniform heating, as in sheet rolling.

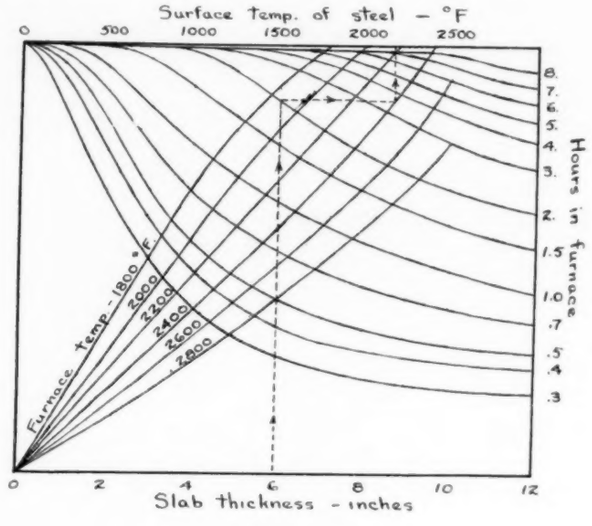

FIG. 5.

The use of the last two methods requires a certain amount of mathematical skill, which it is desirable to eliminate in setting up a guide for heaters and shop men. Charts are therefore presented in Figures 1, 2, 3, 4, 5 and 6, from which can be ob-

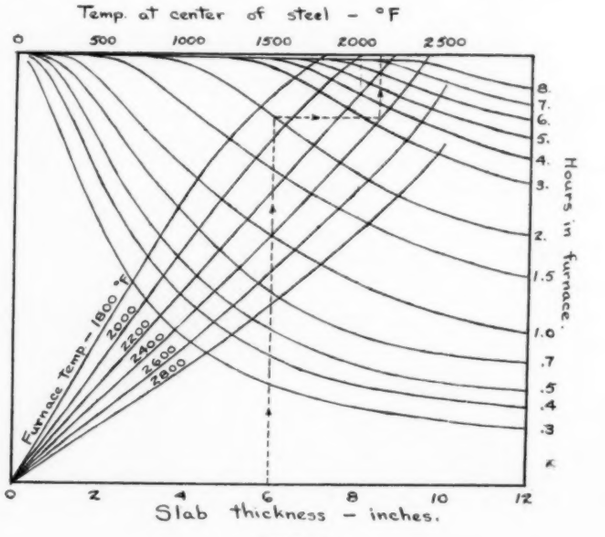

FIG. 6.

tained both surface and center temperatures in a given piece of stock after any desired time in a furnace of given temperature. These charts are constructed from the method of Gurney and Lurie, for common mild steel. Heat transmission co-efficients required in the calculations are taken as 10 at 1400° F., 20 at 2200° F., and 40 at 3000° F., which repre-

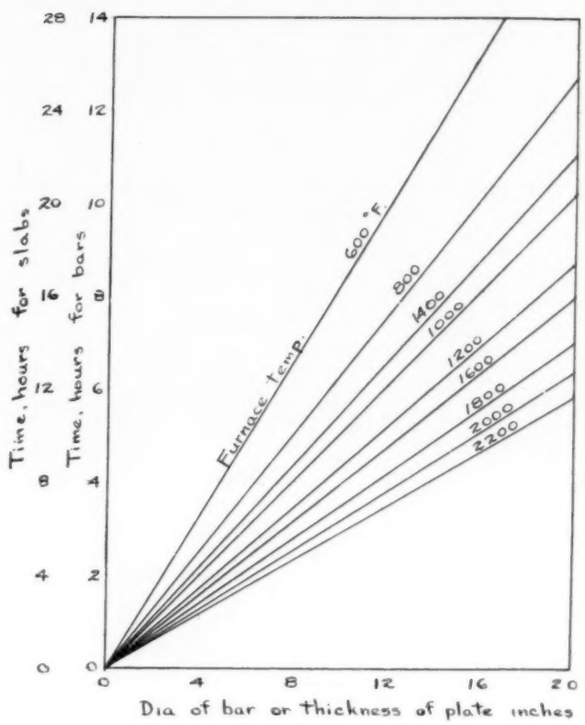

FIG. 7.

sent average conditions. Cases varying widely from the average may produce somewhat different results.

As mentioned above, these charts should be used only in heating for ordinary rolling or forging, and not for very even saturation, or for temperatures near the critical range. The charts are simple, the method of use being to project from stock size on the base-line vertically to the time curve, then horizontally to the curve of furnace temperature, then vertically to the top line, where the temperature is read.

Janitzky's formula is presented graphically in Figure 7, and is self explanatory. It should be used in work demanding great uniformity of temperature, or with temperatures near the critical range.

These curves, while based on mathematical analyses of the subject, seem to check satisfactorily with available data from actual tests. Thorough checking has been impossible due to absence of complete test data. Some discrepancies will no doubt be found, of which the writer will be glad to be informed. However, the charts are presented as a step towards a definite guide for determination of heating time, and the values they give will be found fairly accurate in the majority of cases.

Spoilage of Material Due to Grease Drippage From Overhead Traveling Cranes

By T. J. FLAHERTY *

In every competitive industry there is a tendency to make the inspection standards on finished products more rigid all the time. This condition is brought about by the desire of the manufacturer to improve his product and thereby widen the market for his goods, or by the demands of his customers for material that can be used with a minimum loss. This is especially true in the manufacture of high-grade or specialty iron and steel sheets. It is more especially true in periods of business recession when customers are far more critical than they are under normal conditions.

T. J. FLAHERTY

The manufacturer of high-grade sheets must therefore exercise extreme care to prevent damage to sheets in process or to finished sheets from all sources if he is to keep rejections at a reasonable value. It is the purpose of this paper to discuss one of the sources of damage to sheets that can be controlled in a large measure by maintenance men, and that is sheet spoilage due to oil and grease drippage from overhead traveling cranes.

This type of damage has always been very troublesome to operating men because if sheets are rolled with grease on them the grease is rolled into the sheet and the roll is apt to be damaged at the same time. This results in a stained sheet that is especially objectionable if the sheet is to be painted or enameled. If sheets with grease on them are pickled, some of the grease flows off the sheet due to heat, and collects on top of the bath since the grease is

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not soluble in most pickling solutions. The result of this is that clean sheets may pick up some of this grease when they are withdrawn from the bath, and a stained sheet again results. Grease stains that are embedded in the sheet can only be removed by re-annealing to form a heavy scale and by re-pickling to kick off this heavy scale which carries with it the stained portion of the sheet. It is needless to say that such retreatment is costly and objectionable from every standpoint.

It is obvious that all sheets damaged by oil or grease are not chargeable to overhead cranes. Much of it is caused by pick up from conveyor chains, rolls, and conveyor belts. We have also encountered some trouble from drippings of impregnating compound from overhead open wiring. This condition was caused by very high temperatures existing in some of our buildings. Drippings of this nature leaves a tarry deposit on the sheet that can be removed by a solvent such as carbon tetrachloride if it is noticed before further processing. If it is allowed to remain on the sheet, a stain will usually result that is very similar to a grease stain. This source of damage is troublesome because it is often difficult to determine just where the drippings are coming from. The remedy for this condition is to avoid the use of weatherproof wire in buildings where high temperatures are likely to be encountered.

To get back to our subject, oil and grease drippings from overhead cranes is a constant source of sheet spoilage unless the means are taken to guard against this type of damage. The development of anti-friction bearings together with the progress the grease and oil companies have made in producing lubricants that are practically non-flowing within wide limits of temperature have done much toward eliminating drippage of lubricants from cranes.

It is apparent that should we have a perfect bearing fit in the common types of sleeve bearings and a faultless method of applying the lubricant, excess lubricant would be eliminated and drippage would not be a problem to control. Fully realizing that such conditions are not obtainable on most cranes, the maintenance man with some of the older types of cranes must devise other means of preventing drippage.

In days gone by one grade of grease and possibly two grades of oil constituted the category of crane lubricants regardless of the type of work expected of the crane. Operating conditions have now changed in many practices and crane designers and operators have kept pace with these changes. Higher crane speeds have been developed and heavier cranes have replaced those of the lighter type, and less time is available for applying lubricants to cranes. These changed conditions have lead to the development of many types of oil, grease and bearings to meet more exacting demands.

Various methods have been used from time to time to prevent drippage from cranes. These devices were generally in the form of drip pans suspended below the bearings, or an absorbent material such as waste was used to take up the excess lubricant after it had passed through the bearing. Such devices constitute fire hazards even when they are changed frequently.

We do not claim to have eliminated grease and oil drippage from cranes in our plant entirely, but we have reduced this source of damage to a great extent in certain buildings where oil or grease drippage would result in damage to finished or semi-finished product.

Some of our cranes are fully equipped with roller bearings, some are partially equipped with roller bearings, and some of the older cranes are equipped with sleeve type bronze bearings on the shafting and M.C.B. type track wheel journals on the end trucks. The roller bearing cranes do not give us much trouble from the standpoint of grease drippage as these bearings are practically oil tight. We have eliminated the use of wool waste and oil on certain of these cranes that are equipped with M.C.B. journals and have been using a semi-solid grease which has been giving very good results. The chief objection to this method of lubrication is that it is necessary to punch up the grease frequently to make it come in contact with the axles. We have devised a method of holding the grease in contact with the axles by means of springs that has proved very successful, inasmuch as it eliminates the necessity of punching up the grease every eight hour turn. On a test on one of our busy cranes, we have found that this method provides good lubrication for as long as thirty days without punching the grease up or adding additional grease.

We have found that it is very difficult to maintain cable dressing on our hoist cables and still prevent drippage from this source. In fact, we do not apply any cable dressing to the cables on particular cranes. This practice probably shortens the life of the cable somewhat, although internally the cable seems to have sufficient lubrication that was placed there during the manufacture of the cable.

Leakage from gears is difficult to control and the only remedy we have found is to provide gear cases as near leak proof as possible, and to maintain them that way.

Motor bearings of the oil-ring, oil-cellar type are responsible for considerable leakage, especially if the oil overflows do not have oil-tight covers. The motion of the crane causes the oil level to change and the proper oil level is hard to maintain over long periods, therefore constant attention is required on these bearings. In our back-axle motor bearings instead of oil, we use a semi-solid grease that remains in contact with the journal.

On hook blocks that are equipped with sleeve type bearings, we use the pressure method of applying a not too fluid grease. When applied frequently and in small quantities, it is possible to keep drippage from this source at a minimum. The bearing block with anti-friction bearings is no doubt preferable in service where there is danger of spoiling sheets from oil or grease drippage.

We do not pretend to have carried this particular phase of crane lubrication to any advanced state, and our purpose in preparing these remarks was to throw this subject open for discussion, so that we might learn what is being done in other plants along this line.

Steubenville Works, Wheeling Steel Corporation

Electrical Equipment of the Slabbing and Hot Strip Mills at the Wheeling Steel Corporation's Steubenville Plant

By JAMES FARRINGTON
and
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Electrical Equipment of the Slabbing and Hot Strip Mills at the Wheeling Steel Corporation's Steubenville Plant

By JAMES FARRINGTON† and H. A. WINNE*

Among the most outstanding mill installations made in recent years are the 45" reversing Universal slabbing mill and the continuous hot strip mill at the Steubenville, Ohio, plant of the Wheeling Steel Corporation. These mills, together, with their auxiliaries, are electrically driven throughout. The electrical equipment is of particular interest, both because of its magnitude and of the many novel features involved. The slabbing mill is the first in this country, and so far as we know in the world, to have the horizontal and vertical rolls driven by two separate reversing motors. The strip mill can roll wider strip than any other continuous hot strip mill now in operation. The combined capacity of the main driving motors on the strip mill is 25,650 h.p., continuous rating, making it the most highly powered mill in the world. Rotating electrical apparatus, totaling over 68,000 KW in capacity, is installed in a single motor room 40 ft. wide by 560 ft. long.

Electrical power for this entire installation is purchased from the Ohio Power Company at 66,000 volts-3 phase-60 cycles. At an outdoor substation, located on the mill property, this is transformed to 22,000 and 6600 volts. The 6600 volt power is delivered to the motor room of the slabbing and strip mills, while the 22,000 volt power is distributed to other parts of the mill and to the coke plant which is located on the opposite bank of the Ohio River. In the 60" mill motor room the 6600 volt power is converted to direct current by motor-generators and supplied to the main driving motors.

This article describes the complete electrical installation, starting with the incoming 66,000 volt power lines, carrying through the Ohio Power Company's Fort Steuben substation, the Wheeling Steel Corporation's outdoor substation, and on to the 60" mill motor room and the main and auxiliary drives. A short description of the mills themselves is also included.

The Fort Steuben Sub-Station

The Fort Steuben sub-station was constructed by the Ohio Power Company for the sole purpose of serving the Steubenville Plant of the Wheeling Steel Corporation in a manner that would not only provide sufficient capacity, but would also insure maximum continuity of service. This station was completed and energized December 1, 1928. It consists of an outdoor bus structure, with a brick switch-house housing the instrument and control equipment.

The sub-station is served by four 66,000 volt transmission lines of approximately 40,000 KVA capacity each, carried on steel towers. Each phase of each line consists of a 338,000 c.m. aluminum cable reinforced with steel. The conductors are spaced approximately 12 feet apart at the corners of a triangle. The insulator used is an Ohio brass #25622 disc type with five units in the suspension group and six in the strain insulators. Two of the incoming lines connect directly with the 66,000 volt bus at the Windsor Power Station. The other two lines connect with the 66,000 volt bus of the Ohio Power Company's Wilson Avenue sub-station at Steubenville, which in turn is connected with the Windsor

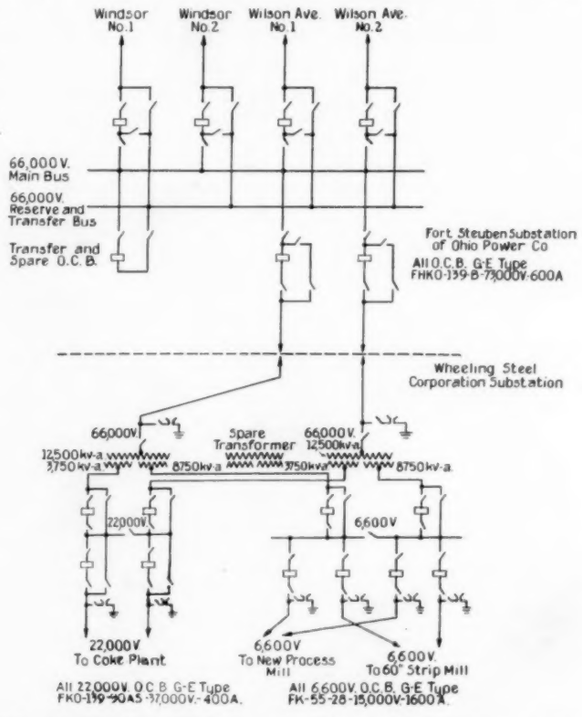

FIG. 1—One-line diagram of main high tension circuits, Fort Steuben and #7 substations.

Plant by two 66,000 volt transmission lines of approximately 40,000 KVA capacity. The line distance from the Fort Steuben Sub to the Windsor Plant is approximately 14 miles.

An elementary diagram of the main connections for the sub-station is shown in Figure 1. The incoming lines enter through General Electric type FHKO-139-B-73,000-volt-600 ampere automatic oil circuit breakers, having an interrupting rating of 1,000,000 KVA at 73,000 volts. The lines are relayed for reverse power overload, balanced power

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and straight overload. Thus if a line fault should develop on any one of the four incoming lines, this line would automatically clear itself without interrupting service to the bus. The current for the relays is furnished by bushing current transformers on the bus side of each breaker.

Each of the incoming line breakers is provided with automatic reclosing relays. The breakers are a-c. motor operated for closing, power for the operating motors being supplied by service transformers connected on the line side of the oil circuit breakers. In case of a transient line fault which may cause a breaker to open without serious damage to the line, the breaker will automatically reclose after 15 seconds, eliminating the delay which would ensue if the breakers were manually operated. The service transformer being connected on the line side of the breaker prevents closing until the line is energized from the source, and thus prevents closures on line faults.

The station has a main operating and an auxiliary bus, with a bus tie breaker. This permits by-passing any breaker in the station, and enables the apparatus to be serviced without interrupting the circuits or endangering service to the bus by connecting the lines directly to the operating bus without relay protection.

The service to the Wheeling Steel Corporation's Sub-station is furnished over two 66,000 volt circuits of approximately 40,000 KVA capacity each, leaving the station through automatic oil circuit breakers. These breakers are relayed for straight overloads and have all the by-pass facilities of the main breakers.

The station is protected against bus faults by a bus differential relay system, in which the current in the incoming lines is balanced against the current in the outgoing feeders, and a case of bus failure will clear every breaker in the station, disconnecting the automatic reclosing feature through an auxiliary relay and preventing re-energizing the station until the fault is cleared and the relay reset.

The breakers on the feeders to the Wheeling Steel bus are provided with differential trips from the Wheeling Steel Corporation's transformer system. This will clear the breakers almost instantaneously in case of transformer or bus fault at the Steel Corporation's sub-station and reduces to a minimum the possibility of serious damage.

The station is equipped with a complete oil purifying system including clean and dirty oil storage tanks, with pipes connected to all oil filled apparatus and the necessary pump and filtering equipment, together with a testing outfit.

The control building houses the instrument and control panels, as well as a 24 volt d-c. battery which is used for tripping the oil circuit breakers. A Tungar charger keeps this battery fully charged at all times.

Outdoor Transformer Station #7

From the Fort Steuben sub-station the 66,000 volt power is carried across the street which passes between the Fort Steuben sub-station and the Wheeling Steel Corporation property, to the outdoor transformer station, located on mill property. There are two 3 phase lines between the two stations, each consisting of 338,000 c.m. bare aluminum cables, steel reinforced, per phase. A diagram of the main connections at the Wheeling sub is shown in Figure 1. Each incoming line passes through gang operated disconnecting switches to the high voltage side of a bank of three single phase transformers. Each transformer is a General Electric single phase, oil insulated, self cooled, 60 cycle unit with three windings. The high voltage winding has a rating of 4167 KVA and is designed for delta connection on a 66,000 volt system, with taps for 69,300/67,650/66,000/64,350/62,700 volts. The secondary winding has a capacity of 1250 KVA at 13,940/13,590/13,245/12,895/12,550 volts, designed for Y connection on a 22,000 volt system. The tertiary winding is rated 2917 KVA at 6900 volts for delta connection on a 6600 volt system.

Thus the capacity of each three phase bank is 12,500 KVA at 66,000 volts, 3750 KVA at 22,000

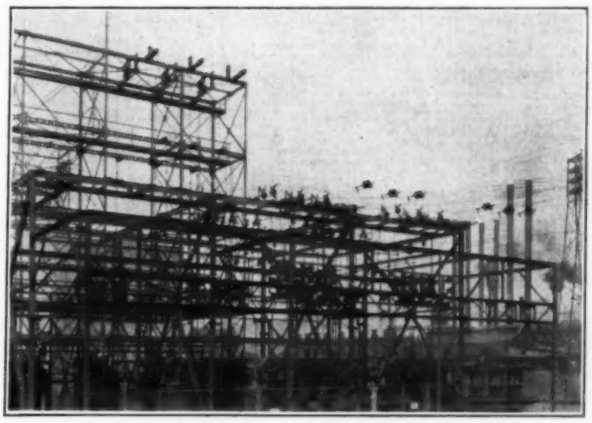

FIG. 2—22 Kv. side of outdoor sub-station #7.

volts, and 8750 KVA at 6600 volts. There are two transformer banks in the station, making the total capacity 25,000 KVA, and the entire station is laid out so that at any time in the future a third incoming line and 12,500 KVA transformer bank may be added. The station includes a spare single phase unit. All transformers are mounted on wheels, and a transfer truck makes it possible to put the spare unit in place of any operating unit in a very short time. The truck may also be used to run a transformer into the control house for repairs.

By the addition of blowers and suitable ducts to provide for air cooling of the external surfaces of the transformer tanks, at any time in the future the capacity of each bank can be increased from 12,500 KVA to approximately 17,000 KVA continuous.

The question may be asked as to why power is distributed at both 22,000 and 6600 volts. 6600 volts was selected as the most suitable voltage for the strip mill motor room and for future extensions, because motor-generators and main driving motors, down to 500 h.p. or less, can economically be built for operation at this voltage, and at the same time the voltage is high enough so that excessive currents do not have to be handled. However, previous to the installation of this new equipment, the Wheeling Steel Corporation purchased 22,000 volt power from the West Penn Power Company for operation of its coke works, which are located across the river from the main mill. This 22,000 volt power also supplied various power requirements in the main mill. Rather than change all of this equipment over for operation at 6600 volts, it was deemed desirable

to make provision for obtaining the 22,000 volt power from the new sub-station and, consequently, the transformers were built with both the 22,000 and 6600 volt windings.

Oil Circuit Breakers

The oil circuit breakers on the 22,000 volt circuit are type FKO-139-30-AS, 37,000 volts-400 ampere outdoor units, with an interrupting rating of 520,000 KVA at 25,000 volts. The oil circuit breakers on the 6600 volt system are FK-55-28"-15,000 volts-1600 ampere indoor type breakers, each mounted in a weather proof steel housing. These breakers have an interrupting rating of 300,000 KVA at 7500 volts. All breakers are solenoid operated.

As will be seen from the diagram of connections in Figure 1, provision is made for taking any oil circuit breaker out of service without causing a cessation of service over any line, with the exception of the breakers on the outgoing 6600 volt circuits. Here such provision was unnecessary because each of the two lines is amply large to carry the total load which is normally transmitted over both of them.

Control House

A control house, located at the outdoor sub-station, contains control switches for all of the breakers at the sub and also for the outgoing breakers at the Fort Steuben sub. These controls are also duplicated in the strip mill motor room. This building likewise houses a control battery and battery charging motor-generator set to provide power for operation of the breakers.

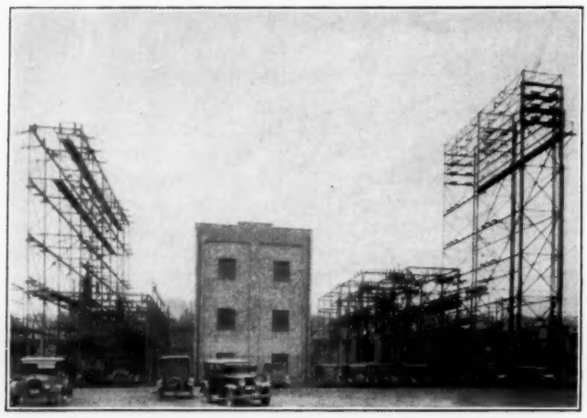

FIG. 3—General view of # 7 sub-station—66 kv. Circuits at the left, with 22 Kv. and 6.9 Kv. at the right.

One end of the control house is arranged for repair of transformers and oil circuit breakers. A 15-ton crane is provided at a sufficient height so that transformers can be completely disassembled and repaired in the house. Provisions are also made for oil storage, and filtering and cleaning the oil.

From an inspection of the connection diagram it will be apparent that continuity of operation was considered of paramount importance. It was for this reason that two banks of transformers, rather than a single one of larger capacity, were installed. Relaying protection is provided so that in case of a fault in any transformer bank that bank will be immediately disconnected from all circuits, leaving the other bank still in operation and carrying the load. As has been previously mentioned, any breaker may be taken out of service without interfering with operation, and the overhead lines between #7 sub-station and the motor room are protected in such a way that trouble in one line results in its immediate disconnection from the system, leaving the remaining line in service carrying the load.

22,000 Volt Feeders

From the #7 sub-station, the 22,000 volt system goes to #4 sub-station over two lines, each consisting of #2/0 stranded bare copper, strung overhead on steel towers and supports. Lines are spaced 30" between phases and 36" between circuits.

From #4 sub-station, two 22,000 volt lines are carried across the river to #1 sub-station containing four Westinghouse single phase, oil insulated, 667 KVA, 22,000-2200 volt transformers for general power supply at the Coke Works, protected by 22,000 volt fuses.

From #7 sub-station there are four 6600 volt outgoing circuits. Two of these feed the #8 substation, in which are located motor-generators supplying power to cold strip mills. Each of these circuits consists of one 500,000 c.m. conductors per phase.

Two 6600 volt circuits feed the hot strip mill motor room. Each circuit consists of three 500,000 c.m. stranded bare cables per phase, carried on steel towers and supports. The insulators are of the Locke-Hewlett suspension type in two-disc strings. Each conductor is carried on separate insulators. The phases of each circuit are located in a vertical plane. Provision is made so that a third circuit may

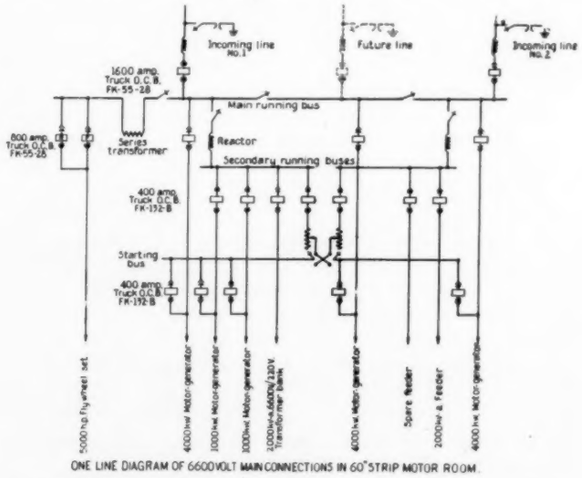
Incoming line No. 1
Future line
Incoming line No. 2
1600 amp. Truck O.C.B. FK-55-28
Main running bus
800 amp. Truck O.C.B. FK-55-28
Series transformer
Reactor
Secondary running buses
400 amp. Truck O.C.B. FK-152-B
Starting Bus
400 amp. Truck O.C.B. FK-152-B
Spare feeder
ONE LINE DIAGRAM OF 6600 VOLT MAIN CONNECTIONS IN 60" STRIP MOTOR ROOM.

FIG. 4—One-line diagram of main 6600 volt connections in the motor room.

easily be added at any time in the future. The spacing between phases in the vertical plane is 4 feet, and between circuits 3 feet minimum. The towers are 90 feet high, spaced on 195 feet centers. Control and metering circuits are carried in multi-conductor lead covered cables strung on messenger wires supported on the same towers and supports as are used for the 6600 volt circuit.

6600 Volt Distribution in the Hot Strip Motor Room

The two 6600 volt lines from the outdoor sub-station enter a pent house on the roof of the hot strip mill motor room through wall bushings, then

passing through disconnecting switches and choke coils. From the pent house the two circuits are carried down to the main 6600 volt bus in the motor room with two 1,500,000 c.m. varnished cambric insulated cables per phase. The cables are laid in fibre conduit embedded in concrete. Lightning arresters are mounted in the pent house on the roof.

A diagram of the main connections of the 6600 volt circuits in the motor room is shown in Figure 4. Each incoming line feeds through a type FKR-55-28"-7500 volt-1600 ampere solenoid operated, truck mounted oil circuit breaker. The main bus is divided into four sections by sectionalizing disconnecting switches mounted in steel compartments which form a part of the truck breaker structure. The right hand section is fed by one incoming line. The middle section will, in the future, be fed by a third incoming line, and the next section on the left is fed by the second present incoming line. The extreme left hand section merely serves to isolate the series transformer and oil circuit breakers used in connection with the slabbing mill motor-generator set. The reason for dividing the bus into sections was to insure continuity of service even in the case of remotely possible bus trouble.

The FKR-55-28" oil circuit breakers, with an interrupting rating of 300,000 KVA at 7500 volts, were naturally quite expensive units and, as a very considerable number of breakers were required to take care of the various circuits, it was decided to utilize secondary buses, protected by current limiting reactors, to which the smaller units were connected through lighter duty oil circuit breakers. The arrangement is shown on the connection diagram. Two secondary buses are used, each connected to the main bus through a gang operated disconnecting switch, and a current limiting reactor designed to give 5% drop in a 4250 KVA circuit. These reactors limit the possible maximum short circuit current on the secondary buses to a value which can easily be handled by the FKR-132-B-15,000 volt-400

FIG. 5—Main truck type oil circuit breakers in gallery in motor room.

ampere truck type oil circuit breakers with interrupting ratings of 60,000 KVA at 7500 volts. Therefore, all breakers on the secondary buses, as well as those on the starting buses, are of this type.

The synchronous motors of the three 4000 KW motor-generator sets, which supply power to the strip mill main drives, and the induction motor of the slabbing mill set all operate directly from the main bus through 800 ampere FKR-55-28" truck type oil circuit breakers. The remaining 6600 volt apparatus operates from the secondary buses.

All of the motor-generators are started at reduced voltage obtained through two auto transformers, which feed the starting bus. The starting bus is divided into two sections, with disconnecting switches arranged as shown so that each section may be connected to an individual auto transformer, or both may be connected to either auto transformer. One auto transformer is connected through an oil circuit breaker to each secondary running bus. Each auto transformer is capable of starting all of the apparatus in succession, and they are designed to withstand continuous excitation.

The main FKR-55-28" oil circuit breakers are located in a gallery at a level of 12.5 ft. above the main floor of the south end of the motor room. The secondary and starting breakers, together with the bus reactors and auto transformers, are placed immediately beneath this gallery. The starting and secondary breakers are arranged back to back in two groups with bus reactors and starting auto transformers in the space between the two groups. All sectionalizing disconnecting switches are mounted in compartments forming a part of the truck structures. This arrangement of breakers has resulted in a very compact and neat installation as is evident from some of the illustrations.

It is apparent from the connection diagram that in the motor room as well as in the outdoor substation continuity of service has been considered of paramount importance. Truck type breakers and bus structure have been used throughout and, even though this is almost absolutely trouble proof, buses have been sectionalized and duplicate apparatus provided so that any ordinary case of trouble could not cause a complete shutdown.

A storage battery and battery charging motor-generator set are located in a battery room on the main floor, to provide power for operation of all oil circuit breakers. The main 6600 volt instrument and control board is located on the main floor in the south end of the motor room.

Slabbing Mill Drive

The reversing universal slabbing mill is driven by two separate d-c. reversing motors, one driving the horizontal rolls and one the vertical rolls. The

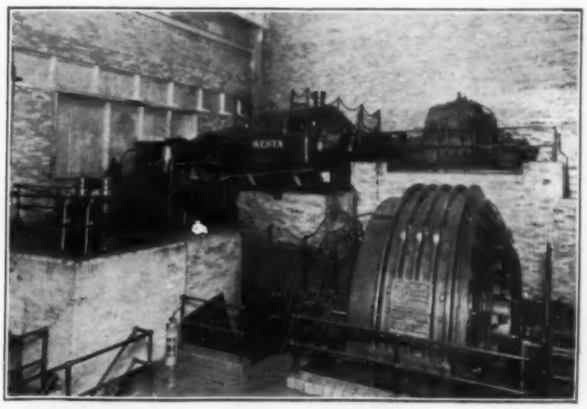

FIG. 6—7000 h.p. and 1650 h.p. reversing motors driving horizontal and vertical rolls of slabbing mills.

horizontal roll motor is rated 7000 h.p. (50 deg. continuous)—50/100 r.p.m.—750 volts. As is usual in reversing mill practice, it will carry very heavy overloads, being capable of delivering 225% of its normal rating torque as often as may be required during the rolling of every ingot, and in emergencies it will develop 275% torque without serious sparking.

The motor driving the vertical rolls is rated 1650 h.p. (50 deg. continuous)—112.5/270 r.p.m.—750 volts. It is capable of carrying the same percentage overloads as the horizontal roll motor.

The 7000 h.p. motor drives the horizontal rolls direct through a 2-high pinion stand. The 1650 h.p. motor drives the vertical rolls through bevel gears and a herringbone reduction gear. The ratio of the bevel and spur gears in the vertical drive is such that with the vertical motor running at 112.5 r.p.m. and the horizontal motor running at 50 r.p.m. the peripheral speed of the vertical rolls will be the same as that of the horizontal rolls, providing these rolls are of the normal diameters.

Power is supplied to the two slabbing mill motors by a flywheel motor-generator set consisting of three 2400 KW (50 deg.)-400 r.p.m.-750 volt generators, a 5000 h.p.-6600 volt induction motor, and a 160,000 h.p./sec. flywheel.

The exciter set for the slabbing mill drive consists of six units, a 75 KW-1200 r.p.m.-250 volt machine for exciting three generators, a similar unit for exciting the 7000 h.p. motor, a 20 KW-250 volt exciter for the 1650 h.p. motor, a 1 KW series exciter for use in connection with the 1650 h.p. motor, a 15 KW-250/250 volt compound wound machine to supply control power and excitation for the other exciters, and a 250 h.p.-220 volt induction driving motor.

The control for the 5000 h.p. induction motor of the flywheel set consists of forward and reverse FKR-55-28" oil circuit breakers in the stator circuit, and a liquid slip regulator in the secondary. This slip regulator not only automatically limits the power input to the induction motor by regulating the speed of the set, permitting the flywheel to deliver and receive energy, but is also used to limit the current input when starting the set from rest or when plugging it to standstill. The regulator is equipped with a motor driven mechanism such that whenever both forward and reverse oil circuit breakers are open, the electrodes are automatically separated to the maximum resistance position and the breakers can not be closed until the electrodes are in this position.

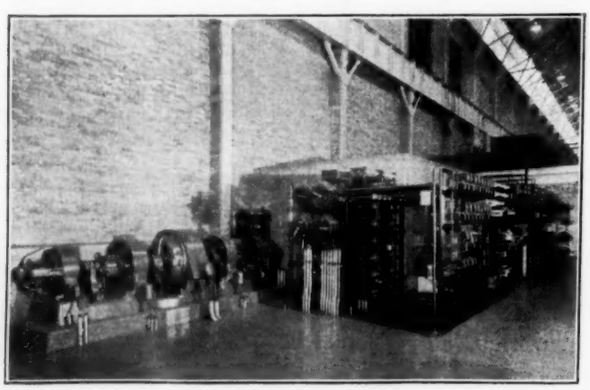

FIG. 7—Exciter set and control for reversing universal slabbing mill drive.

The three 2400 KW-750 volt d-c. generators are connected in parallel, with a circuit breaker in one lead and a lever switch in the other lead from each armature. So far as we are aware this is the first time that three generators have been operated in parallel on a reversing mill drive and, in order to insure equal division of the load between the three machines, under all conditions of voltage from zero to maximum in either direction, the following scheme was adopted. Each generator has two separate and distinct series field windings, with an equal number of turns in each, one connected cumulatively and the other differentially. The armature current of generator A is carried through its own differential series field and through the cumulative series field of generator B. The armature current of generator B is carried through its own differential field and the cumulative field of generator C. The armature current of generator C is carried through its own differential field and through the cumulative field of generator A. Then if generator A tries to take too much load, due possibly to slightly different resistance in its armature circuit, or to other causes, the effect of its differential field will be slightly greater than that of its cumulative field, and its voltage will be reduced. Simultaneously the excess current from generator A. flowing through the cumulative field of generator B, causes a slight increase in the voltage of generator B, thus increasing its output slightly and thereby in turn increasing slightly the output of generator C. The result is that the system at all times remains balanced and the scheme has proven extremely effective.

The 7000 and 1650 h.p. motors are connected to the 750 volt bus through solenoid operated circuit breakers in one line and lever switches in the other.

The control of the speed and direction of rotation of the two motors is by a combination of generator field and motor field control. The three generator fields are connected in series and excited from a 75 KW exciter. The direction and amount of excitation is controlled by contactors and resistors in this field circuit. The speeds of the main motors from zero to their basic speeds of 50 and 112.5 r.p.m. respectively are controlled through adjustment of the generator field excitation. Each motor is excited from a separate exciter and the amount of motor field excitation is controlled by means of contactors and resistors in the respective exciter field circuits.

All of the generator and motor field contactors are under control of a foot operated master switch located in the operator's pulpit and to accelerate both motors in either direction he has merely to depress one or the other of two foot pedals.

It is obvious that, as the rolls wear down and new rolls are substituted, the ratio between the diameter of the vertical rolls and that of the horizontal rolls will change, thus necessitating an adjustment of the ratio between the speeds of the two motors in order to maintain equal peripheral speeds of the rolls. This is accomplished by making the various sections of resistance in the vertical roll motor exciter field adjustable by means of a multi-dial rheostat. This rheostat not only adjusts the amount of field current for each of the two motor field operating points, but also for the basic speed as well. The

values of resistance on the three dials are very carefully proportioned so that when the basic speed of the vertical roll motor is adjusted in the proper ratio to that of the horizontal roll motor, the motor speed points will automatically also be in the proper ratio. This multi-dial ratio adjusting rheostat is hand operated and located in the mill pulpit where it can easily be set by the operator. One of the dials is connected in series with a voltmeter across the exciter bus, this meter being calibrated so that it gives a closely approximate indication of the speed ratio for which the rheostat is set.

A small compounding exciter is used in connection with the vertical roll motor to give it a slightly drooping speed load characteristic so that in case the speed ratio is not adjusted correctly the compounding action of the exciter will prevent the vertical roll motor being seriously overloaded.

When the slab is going through the mill in the direction from the horizontal rolls to the vertical the ratio of horizontal roll r.p.m. to vertical roll r.p.m. must be lower than for the reverse direction. In the first case the peripheral speed of the horizontal rolls is approximately the same as the speed of the slab in the space between the two sets of rolls. In the second it is higher by a percentage approximately equal to the percent reduction being made in passing through the horizontal rolls.

To accomplish this change in ratio a resistor is inserted in the field circuit of the horizontal roll motor and a contactor provided so that when the ingot is traveling from the horizontal rolls toward the vertical rolls the resistor is short circuited. For the opposite direction the contactor automatically opens, thus increasing the speed of the main roll motor.

This system of speed control of the two motors has proved perfectly satisfactory and the motors hold the proper ratio of speed from zero to maximum speed in either direction. A tachometer generator is provided on each motor, and speed indicating meters are located in the mill operator's pulpit. Here also are instruments showing the load on each motor. Indicating and recording instruments for voltage, armature currents, field currents and speed are provided on the switchboard in the motor room.

Hot Strip Mill Drive

The continuous strip mill consists of a total of eleven stands. The first two are driven by one d-c. motor, while the remaining stands are all individually driven. The motor ratings and speeds are as given in the following table:

Stands	Motor HP	Motor RPM
1-2	4000	300/400
3	3000	200/400
4	1200	250/500
5	1200	250/500
6	1500	220/440
7	2300	200/400
8	3000	200/400
9	3000	200/400
10	3000	200/400
11	3000	200/400

All of these motors are designed for operation on 600 volts, with fields excited at 250 volts. They are rated on the basis of 40 deg. C. rise continuously and capable of carrying maximum loads of 200% of normal. They are of heavy mill type construction throughout. Each is equipped with speed limit switch, bearing temperature relays, tachometer, and electric heater.

There are three vertical edging rolls, one set preceding each of stands 3, 4 and 5. Each pair of edging rolls is driven by an MD-418-150 h.p.-450/1200 r.p.m. force-ventilated motor. The #3-A edger drive operates at 600 volts, while the remaining ones operate at 250 volts for reasons which will be explained later.

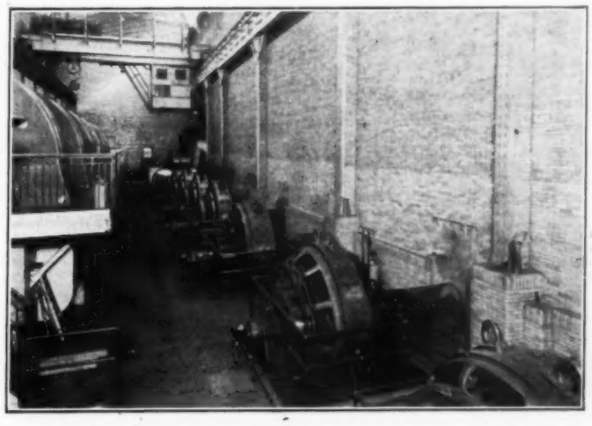

FIG. 8—D.C. Motors driving last seven stands of 60" continuous hot strip mill.

Direct current power for the strip mill main roll motors is supplied by three 4000 KW, 3-unit motor-generator sets, each consisting of two 2000 KW-514 r.p.m.-600 volt generators, and one 5300 KVA-.85 PF -514 r.p.m.-6600 volt synchronous motor. The generators and motors are all separately excited at 250 volts d-c.

The exciter set for the strip mill drive consists of one 250 KW-1200 r.p.m.-250 volt main exciter for supplying fields of the motor-generators and motors; one 20 KW-125 volt machine used as a counter-e.m.f. generator in connection with voltage regulation on the main generators; one 48 KW-60 volt generator used to supply power for jogging control of the screwdown motors on the strip mill stands; and one 400 h.p.-220 volt-60 cycle induction driving motor.

The switchgear equipment for the synchronous motor on each motor-generator set consists of a main FKR-55-28" truck type oil circuit breaker, an FKR-132-B breaker for connecting to the starting bus, and necessary instruments and relays. The switchgear is arranged for automatic pull button starting. To start a unit the operator simply turns a single control switch, after which the complete starting and synchronizing operation takes place automatically.

Each d-c. generator and motor is connected to the main 600 volt bus through two solenoid operated MC-2 air circuit breakers, one in each side of the line. The 600 volt bus is divided into two sections by solenoid operated bus tie breakers so that, when desired, the 4000 h.p. motor on stands 1-2, the 3000 h.p. motor on stand 3, and two 2000 KW generators can be segregated on one section of the bus. This division of the mill bus is necessitated by requirements of mill operation. With motors 1-2 and 3 operating at normal voltage, the delivery speed of stand 3 is much in excess of the maximum entering

speed in stand 4, i.e. stands 3 overfeeds. The spacing between stands 3 and 4 is sufficient so that when 5 ft. slabs are being fed into the mill they will run free between stands 3 and 4, and consequently the first two motors are operated at normal voltage under this condition with the steel leaving stand 3 at high speed and then slowing down on the table between stands 3 and 4. For this method of operation the bus tie breakers are closed and all six generators operate in parallel.

FIG. 9—Three 4000 KW. motor-generators, in gallery at left, with air circuit breakers above.

When rolling from 11 ft. slabs, or ingots, as is sometimes done, the steel reaches from stand 3 to stand 4 so that the speeds of the first three stands must be low enough for continuous operation with the rest of the mill. This necessitates lowering the voltage on the first two driving motors to about one-third or one-half of the normal value, and to do this the bus tie breakers are opened and the one motor-generator set and #1-2, #3 and #3-A edging motors, are operated independent of the main 600 volt bus.

All of the main driving motors, with the exception of the edging motors, are started by generator voltage control. An elementary diagram of the main motor and generator connections is shown in Fig. 10. Each generator main field is connected through a load adjusting rheostat and a field switch to the generator excitation bus. This generator excitation bus is fed from the moving contacts of a reversing potentiometer type rheostat, which in turn is supplied with power from the main 250 volt excitation bus. The armature of a counter-e.m.f. generator, which forms a part of the voltage regulating equipment, is connected in series with the power supply to the potentiometer rheostat. The field of the counter-

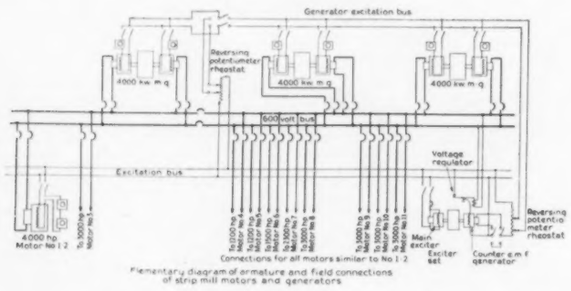
Generator excitation bus
Reversing potentiometer rheostat
4000 kw m g
4000 kw m g
4000 kw m g
600 volt bus
Excitation bus
Voltage regulator
Reversing potentiometer rheostat
Main exciter
Exciter set
Counter e m f generator
Connections for all motors similar to No 1-2
Elementary diagram of armature and field connections of strip mill motors and generators

FIG. 10—Elementary diagram of armature and field connections of strip mill motors and generators.

e.m.f. generator is separately excited through the contacts of a voltage regulator, the coil of which is excited from the main 600 volt bus. This regulator is so adjusted that whenever the voltage on the main bus tends to exceed 600 volts it applies field to the counter-e.m.f. generator, thereby introducing an opposing voltage in the potentiometer rheostat circuit which prevents the generator excitation from exceeding the value required for 600 volts. Whenever the voltage on the main bus is reduced below 600 volts by operation of the reversing potentiometer rheostat, the regulator contacts simply remain open and, under this condition, the counter-e.m.f. generator has no effect on the circuit. The result is that during the starting operation the regulator is automatically rendered inoperative, but as soon as the potentiometer rheostat is adjusted to a position which would permit the generator field excitation to reach or exceed normal value, the regulator takes control and maintains the bus voltage constant.

The fields of the two generators which feed into the section of bus to which motors 1-2 and 3 are connected are arranged so that they can be connected either in parallel with the fields of the other generators, when the bus tie breakers are closed, or to a separate reversing potentiometer rheostat, giving individual control of their voltage, when the bus tie breakers are open.

The operator in the mill pulpit has complete control of the starting and stopping of the mill drives after the motor generators are put into operation by the attendant in the motor room.

The method of starting the mill is as follows: Assuming that the operator in the motor room has started the motor generators and exciter set and has closed the field switches of the generators and motors, the operator in the mill pulpit closes the breakers of the d-c. mill motors by operating control switches located on the pulpit bench. Then by operating a master control switch on the pulpit bench, he closes the breakers of all of the generators which are running and which have their field switches closed. He then starts the mill by simply turning the control switch of the potentiometer rheostat to the forward running position. This causes the potentiometer rheostat to apply and gradually increase the excitation on the generator fields, thus causing the voltage to build up and the motors to start. As soon as the generator bus voltage reaches 600, the regulator assumes control of it. The operator can stop the mill by pulling the generator breaker master trip switch, or by throwing the control handle for the reversing potentiometer rheostat to the zero voltage position. If he first opens the generator breakers the potentiometer rheostat automatically returns to the zero voltage position ready for the next start. The whole mill can be started in the reverse direction by turning the control switch for the potentiometer rheostat to the "reverse" position.

The breakers and field switches are all interlocked so that the operator must follow the proper sequence in starting the mill. Before the breakers on any motor can be closed, the following conditions must be satisfied: there must be field on the motor, as indicated by the field protective relay; the motor must be at rest, as indicated by a voltage relay across its armature; there must be no voltage on the bus, as indicated by the bus voltage relay;

all generator breakers must be open. Before the breakers on any generator can be closed the following conditions must be satisfied: the generator must be running; the generator field switch must be closed; there must be no voltage on the bus; the potentiometer rheostat must be in the zero field position.

A load balancing rheostat is placed in each generator field circuit, with its control switch located

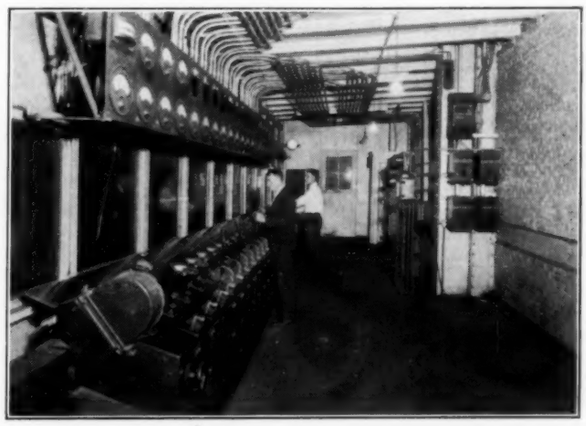

FIG. 11—Operating pulpit of hot strip mill.

on the generator switchboard panel in the motor room. This permits the motor room operator to adjust the division of load between the generators. The generators have no series fields, but no difficulty has been experienced in making them divide the load equally throughout the range from zero voltage to full voltage. The mill is started by bringing up the voltage on all generators simultaneously so that if it is desired to run the whole mill at slow speed for trial operation, the full generator capacity is available at reduced voltage.

No provision is made for applying full field to the motors while starting, as this has proven to be entirely unnecessary on this and other similar installations, and consequently the motors come up to the same speed for which they were adjusted at the time of the last shutdown.

The strip mill pulpit is located on the side of the mill opposite to the motor room. This pulpit contains a steel benchboard with a section for each main roll and edging roll motor, and a section for the six generators. On each motor section is placed an ammeter, a tachometer, a control switch and indicating lamps for the motor breakers, a control switch for the coarse field rheostat, and a lever for the hand operated vernier field rheostat. On the generator sections are placed an ammeter for each generator, a bus voltmeter, generator breaker indicating lamps and control switches, and the control switch for the main reversing potentiometer rheostat. The benchboard is so located that the operator standing at it has a clear view of the mill stands.

The speed of each motor is adjusted at any point within its range by means of two rheostats connected in series in its field circuit. One of these, which covers the entire speed range, is motor operated and used for coarse adjustment of the speed. The other, covering about 15% of the speed range, is operated by means of a lever mounted on the bench and is used for fine adjustment of the speed.

The inherent speed regulation of the motors has proven plenty close enough to meet all conditions of operation and no special speed regulating equipment is used, nor required. The pulpit operator has no difficulty whatever in controlling the "loop" between stands by making slight adjustments of the lever operated rheostats whenever necessary.

Auxiliary Power Supply

In the strip mill motor room is located a bank of four 667 KVA-6600-220 volt transformers, three operating units and one spare, to supply 220 volt power for the driving motors of the exciter sets and various a-c. motor driven mill auxiliaries such as the slab shear and scale breaker. The bus structure is so arranged that the spare transformer can very quickly be connected in the circuit in place of any operating unit. This 220 volt power is distributed over six feeder circuits, each protected by a TP 1200 ampere air circuit breaker. There are also four 200 ampere-110/220 volt lighting feeders which are supplied by three 220/110 volt auto transformers connected to the 220 volt power circuit.

The 250 volt direct current power for the operation of direct current mill auxiliary motors is supplied by two 1000 KW motor-generator sets each consisting of a 1000 KW-720 r.p.m.-250/250 volt generator driven by a 1400 KVA-.8 PF-6600 volt synchronous motor. Each d-c. generator is connected to the 250 volt bus through a 6000 ampere hand operated air circuit breaker and a lever switch.

On the 250 volt system, there are six automatic reclosing feeder panels of 3000 ampere capacity each, supplying power to the auxiliaries on the slabbing and strip mills. Two of these feeders supply #1 control house, two #2 control house, one #6 control house, and one the auxiliary control equipment which is located in the motor room. This bus is connected through a tie line panel to the 250 volt switchboard in #1 power house and in #8 sub-station. The tie lines are of 5000 ampere capacity with eight 800,000 c.m. cables in each line.

General Layout of Motor Room

The entire electrical equipment for the slabbing and strip mills had to be fitted into a long narrow space between the existing 35" blooming and 19"

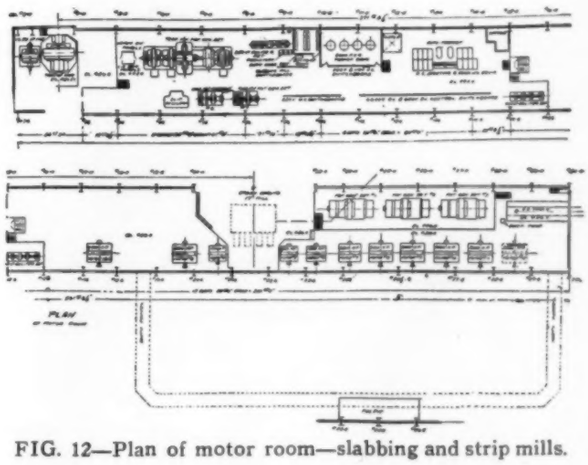

FIG. 12—Plan of motor room—slabbing and strip mills.

continuous mills on one side, and the new slabbing and strip mills on the other. The motor room is approximately 561 ft. long and only 40 ft. wide. This room not only houses the electrical equipment for the new mills, but it also contains the Nordberg Uniflow steam engine which drives the 19" continuous mill.

A diagrammatic plan of the motor room floor is shown in Fig. 12. The main roll motors for the slabbing mill are at the extreme south end of the motor room. The flywheel motor-generator set, the two 1000 KW-250 volt motor-generators, the exciter sets, the instrument and control panels, the 2000 KVA-6600-220 volt transformer bank and the truck oil circuit breakers on the secondary and starting busses are all located in the space between the slabbing mill motors and the 4000 h.p. d-c. motor driving stands #1 and #2 of the strip mill. The floor level of this section of the motor room is at an elevation of 442 ft. above sea level which is approximately 1.5 ft. above the maximum recorded flood stage of the Ohio River, so that all of this equipment is beyond the possibility of damage in case of floods.

The main 6600 volt bus and FKR-55-28 oil circuit breakers are in a gallery at an elevation of 454.5 ft., directly above the secondary and starting oil circuit breakers.

The elevation of the strip mill main motors is, of course, determined by the mill level and the floor of the motor room in the section occupied by these motors is at an elevation of 438 ft., or approximately 2.5 ft. below the maximum recorded flood stage. Every precaution has been taken against the possibility of flooding the motor room in case of high river level. The basement floor and side walls up to an elevation of 442 ft. are of water tight construction. All conduits which enter the basement or motor room from outside have their outside ends carried above maximum flood level. Where the motor shafts pass through the walls of the motor room, special steel casings are set into the concrete walls and water tight packing may quickly be put in place between the shaft and the casing. As an additional precaution, automatically controlled centrifugal pumps are connected to a sump located in the basement.

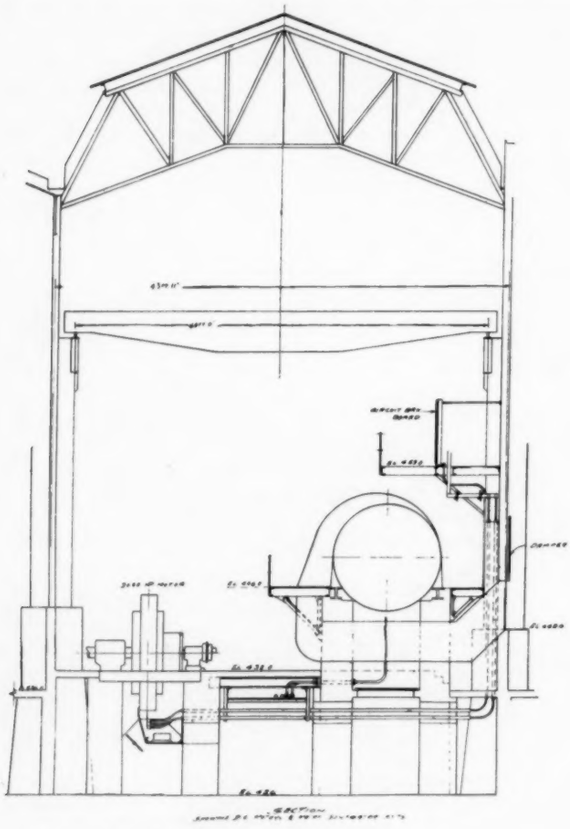

FIG. 13—Elevation of motor room at motor-generators.

Owing to the restricted space available, it was a considerable problem to find locations for the three 4000 KW motor-generator sets. The expedient finally adopted was to carry the foundations of these sets up to a level of 446 ft. and build a gallery at this level. This not only makes possible a passage-way of sufficient width between the main driving motors and the foundations of the sets, but also places these important units above the maximum flood level.

In order to keep the 600 volt d-c. breaker board as close to the motor-generators and motors as possible, this was placed in a gallery located above the motor-generators themselves, at an elevation of 458 ft. The cables from the 600 volt bus drop directly down to the generators and down to the basement and across to the motors.

Two tunnels connect the motor room with the main mill pulpit, one leading from the extreme north end of the room, and the other from a point between motors 1-2 and motor 3. In these tunnels are carried the control cables and conduit leading to the benchboard in the pulpit. The tunnels are of waterproof construction and their openings at the pulpit are carried up above maximum flood level.

With the exception of the 6600 volt cable coming down from the pent house on the roof to the incoming line breakers, all conductors, both a-c. and d-c., consist of lead covered cables. These cables either run in fibre ducts imbedded in the concrete floors and walls, or in galvanized iron conduit in the basement. Approximately 24 miles of lead covered cable were used in installing the main drives, and about 31 miles for the auxiliaries.

Many difficult problems had to be solved in laying out the installation. For example, the foundations of #1-4000 KW motor-generator set straddle a tunnel carrying a 40" exhaust main from the 19" mill engine. The foundation of the 19" mill engine cuts off communication between the north and south ends of the basement so that all electrical cables connecting apparatus in the north and south ends had to be carried in conduits imbedded in the basement wall, or above the engine in the motor room.

Basements are provided under both ends of the motor room and filtered air is supplied to the basements under pressure, and allowed to rise up through openings around the main driving motors and motor-generator sets into the motor room. A damper under each machine regulates the flow of air.

In an underground room adjoining the north end of the basement, there are located four fans, each capable of delivering 60,000 cu. ft. of air per minute. These fans draw air in through air filters of the ACE oil film type, and discharge it into the north basement. In the south basement are located four

60,000 c.f.m. fans and another air filter. One of these fans supplies air directly to the slabbing mill motors which are of the enclosed ventilated type. The other supplies air to the pit beneath the flywheel motor-generator set. The remaining two force air into the basement beneath the 250 volt motor-generators and strip mill motors #1-2 and #3. Thus a total of 480,000 c.f.m. of air can be supplied to the room.

The generators of the 4000 KW and the flywheel motor-generator sets are all provided with ventilating housings of the volute type. These housings are steel plate structures, of the general shape of a fan casing, enclosing the magnet frames and extending radially inward almost to the ends of the armature conductors. These housings collect the heated air thrown out by the generator armatures and discharge it outside the motor room. The driving motors of these sets also discharge ventilating air outside the motor room. This method of ventilation materially

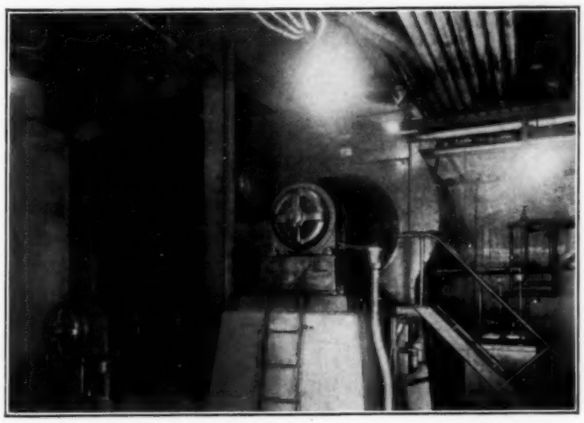

FIG. 14—Two of the eight ventilating fans in the basement of the motor room.

reduces the temperature in the room, making it much more comfortable for the operators.

The motor room walls are finished in yellow glazed brick. The floor is of red tile.

The motor room is lighted by Holophane high bay units with 750 watt lamps in each. Two rows of these lamps extend along the room with 40 ft. spacing between centers.

In the motor room is a crane of 40 ft. span with 50 ton main and 15 ton auxiliary hoist.

Auxiliary Drives

Practically all of the mill auxiliaries are d-c. motor driven and while most of them are of conventional type, a few are so special as to be worthy of description.

The screw-down drive on each four-high stand of the strip mill consists of an MD-412-50 h.p. compound wound 230 volt motor. In order to permit independent adjustment of the screws at each end of the roll, a magnetic clutch is interposed between the motor and each screw. For the control of each screw-down drive, there is provided a master switch, three push button stations, and the necessary control panel and resistors. When the master switch is operated, both clutches are energized and the motor is operated from the 250 volt circuit, raising or lowering both screws simultaneously. One of the push button stations also energizes both clutches, but causes the motor armature to be connected directly to a special 60 volt circuit for a length of time determined by the setting of a timing relay. Therefore, the operation of this button causes both screws

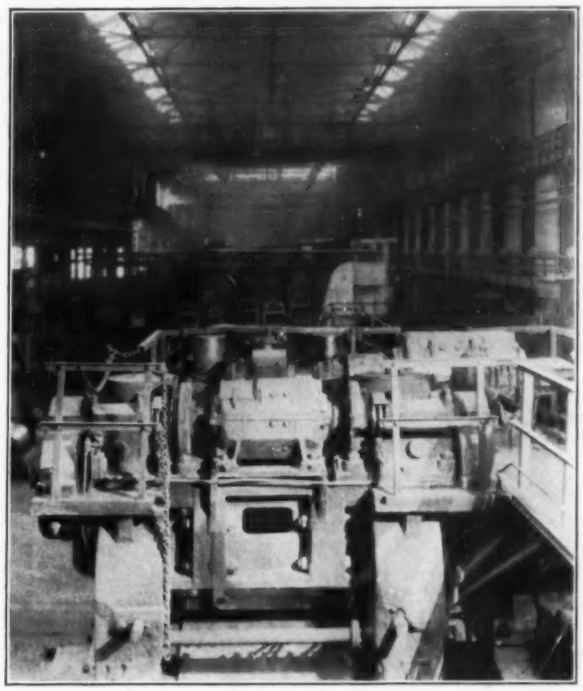

FIG. 15—MD-412-50 h.p. motor driving screw-downs on one stand of hot strip mill.

to be raised or lowered a definite amount. The other two buttons are connected so that they energize either one or the other clutch and also cause the motor to be connected to the 60 volt circuit for a definite length of time, thus raising or lowering either end of the roll a definite amount. The 60 volt special circuit is used for jogging to insure more uniform results than could be obtained if the armature were connected to the 250 volt circuit through a large amount of resistance. This 60 volt power is supplied by a 48 KW generator connected to the strip mill exciter set.

The loopers which are located between adjacent stands of the strip mill from #5 on, are motor operated. Each looper is driven by an MD-410 shunt wound 230 volt mill type motor which operates as a torque motor, making only a very few revolutions for the total travel of the looper. Inasmuch as these motors operate only at very slow speed or at standstill, it is necessary to supply power to them at very low voltage, and to avoid wasting a large amount of power in series resistance, a small 32 volt generator supplies the power for the looper motor armatures. These looper drives may be controlled either by hand operated master switches in the mill pulpit, or automatically by relays actuated by the loads on the main driving motors.

In order to make clear the automatic operation, we will consider the looper between stands 5 and 6. In the armature circuit of each of the main driving motors is connected a load relay so adjusted that it will not operate on the motor load due to the friction

of the empty stand, but it will pick up whenever the motor is loaded due to steel between the rolls. When the strip enters stand #5, the load relay on motor #5 closes its contacts, but this has no effect on the looper between stands #5 and #6. As the strip passes along and enters stand #6, the resultant load on motor #6 causes its load relay to close its contacts. This in turn, so long as the relay on motor #5 remains closed, will actuate the control equipment to apply power to the torque motor on the looper, causing the looper roller to lift up against the under side of the strip and raise it until it is taut between the two stands. The roller is held up against the strip with a pressure dependent upon the torque value for which the looper motor field is adjusted. As soon as the tail end of the strip leaves stand #5, the load relay on motor #5 will drop and this action will cause the control equipment to momentarily reverse the power on the looper motor, causing the looper roller to quickly return to its lower position, and remain there until strip again reaches from stand #5 to stand #6.

There are two Mesta rotary flying shears, one for cutting hot strip and the other for cutting cold strip. Each shear consists essentially of two cylindrical drums, one above the other, with a knife blade mounted on each drum. The two drums are geared together so that they run at different speeds and consequently the knife blades come together and cut the steel only once in several revolutions. Obviously the length of the piece cut can be varied by regulating the speed of rotation of the shear drums with respect to the rate of travel of the strip. Each of the flying shears is driven by an MC-103-150 h.p.-0/1000 r.p.m.-0/400 volt motor. Power for the hot strip shear motors is supplied by a Westinghouse motor-generator set consisting of two 125 KW-0/200 volts-875 r.p.m. generators, and a 200 h.p.-220 volt induction motor, with a 7½ KW exciter. In order that the strip may be cut into uniform lengths, it is essential that the speed of the shear driving motor be synchronized with the speed of the strip itself. This is done by matching the speed of the shear motor against the speed of a set of pinch rolls preceding the shear, by utilizing pilot generators on the shear motor and pinch rolls, and suitable regulating equipment.

The hot shear is started from rest automatically for each piece of strip coming through the mill by means of a load relay actuated by the finishing stand motor. An adjustable timing relay interposed between the load relay and the shear motor control insures that the shear will start at just the proper time to crop a short length from the front end of the strip.

A complete list of the auxiliary driving motors in both the slabbing and strip mills is given at the end of this article.

All auxiliary motors have magnetic control, utilizing definite time control of acceleration. A small amount of the auxiliary control equipment is located in the main motor room, but the majority of it is housed in three control houses in the opposite side of the mill building.

#1 auxiliary control house contains the control for the slabbing mill auxiliaries. This house is completely enclosed and clean air is supplied to it at the rate of 30,000 c.f.m. This is a two-story house with control equipment on both floors.

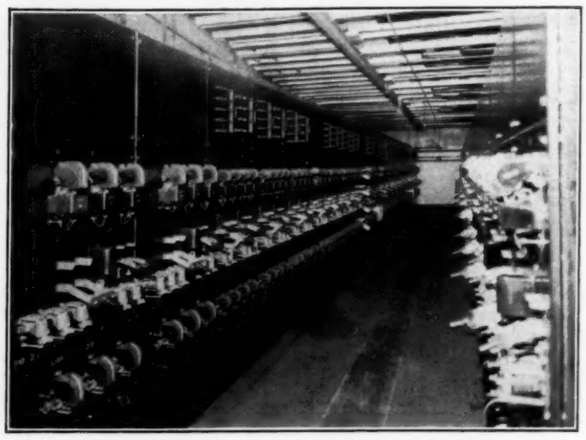

FIG. 16—Auxiliary control house #2.

#2 control house contains on the second floor the control equipment for the hot strip mill. It is also supplied with clean air. The first floor serves as a wash and locker room.

#6 control house contains, on the second floor, the control equipment for the finishing end of the strip mill, while the first floor is used as a mill office.

The control houses are approximately 20 ft. wide x 75 ft. long x 25 ft. high. The control panels are grouped in two rows, face to face, and the resistors are mounted above the control board, with a walkway between the rows of resistors. Spare control panels and resistors for each size of panel are provided in each control house, and a system of transfer switches and busses permits the spare panel to be quickly connected in place of any panel which is in trouble.

Operation of Slabbing and Strip Mills

Ingots are supplied to the 45" reversing Universal slabbing mill approach table by a motor operated ingot buggy. From the approach table, the ingot passes on to the entry table and into the vertical rolls and then to the horizontal rolls. On the delivery side of the mill there is a delivery table, a runout table and a shear table between the mill and the slab shear.

The master controllers for the approach, entry, and delivery tables, the side guards, the manipulator, the horizontal and vertical screws, and the foot operated master switch for the main driving motors, are all located in the mill pulpit.

From the mill, the slab is delivered to a 1000 ton slab shear driven by two 100 h.p. wound rotor induction motors, having a clutch actuated by a 10 h.p., MD-404 motor.

From the shear, the slab may be delivered either to reheating furnaces, direct to the strip mill, or to shipping skids.

The master controllers for operating the shear are located in the shear pulpit.

A 74 ft. span crane with 40 ton main and 10 ton auxiliary hoists commands the slabbing mill.

Some heavy skelp and plate is rolled in the hot strip mill direct from the ingot heat, the slabs going from the slab shear to the strip mill. Slabs for thinner strips are reheated before rolling in the strip

mill. Slabs which are to be reheated are delivered on to a slab conveyor from which they are charged into any one of the three Chapman Stein reheating furnaces, having inside dimensions of 13'6" wide, and 61'8" long. Each furnace will heat approximately 22 tons of cold steel per hour. They are fired with coke oven gas and are equipped with complete temperature recording instruments.

From the furnaces the reheated slabs are delivered to receiving tables by pusher machines located at the back of each furnace, from which they pass into the hot strip mill.

Stands #1 and #2 of the continuous strip mill are of two-high construction. They are given through a tandem, double reduction Herringbone gear set from a single motor. Between stands #1 and #2, #2 and #3, and #3 and #4, are motor driven tables. From stands #4 to #11, there are no motor driven tables, the steel being carried by aprons and idling rollers.

Stands #3 to #11 of the hot strip mill are of 4-high construction, with backing-up rolls carried in roller bearings. Stands #3, #4 and #5 are individually driven through double reduction gears, while the remaining stands are individually driven through single reductions.

After leaving the finishing stand of the strip mill, the strip is conveyed by an adjustable speed motor driven table to the flying shear, to be cut into sheets, or it may be passed through the shear and delivered to either one of two Mesta coilers which reel the strip into coils. The rollers of these coilers are individually driven by small induction motors operated from adjustable frequency motor-generator sets. The expander is driven by an adjustable speed d-c. motor and the coil extractor is actuated by an air cylinder. The extractor delivers the coil on edge to a chain conveyor on which it is carried to a weighing machine at the coil ramp. The coil is then loaded into cars by a crane.

If plates are to be sheared in short lengths, the strips are carried from the shear run-out table to the cold shear run-in table by a transfer chain. From this run-in table, the strips are either delivered to a Mesta plate shear or to the cold flying shear previously mentioned. From the flying shear, they pass through a leveler.

In the hot strip mill there is one crane with 74 ft. span, having a 60-ton main hoist and a 15-ton auxiliary hoist. In the finishing end of the building are two 45-ton cranes with spans of 94 ft. In the coil shipping building is another 25-ton crane with a span of 82 ft.

The lighting in the mill building is furnished by Holophane, high bay, 750-watt units, spaced 40 ft. apart along the length of the building, in three rows with 25 ft ,spacing between adjacent rows and 12 ft. between each outside row and the wall.

The operation of the entire equipment has been very satisfactory from the very beginning. The first ingot went through the slabbing mill without difficulty, and the first slab went through the strip mill and coiler without cobbling.

The experience with purchased power has been very satisfactory, there having been no power interruptions since October 23, 1929 when an insulator bushing at the Fort Steuben sub-station grounded. The mill was not running at the time of this ground, so no delay was incurred. The total interruption caused by power failures from January 19, 1929, when power was first delivered to the motor room, until November 15, 1930, amounts to only 45 minutes, which is an extremely good record.

The operating record of the electrical equipment on the mills is also excellent. The total delays on the 45" slabbing mill charged against the main drive equipment in this period of practically 22 months is only one hour and 45 minutes, and on the continuous strip mill two hours and ten minutes. A part of these delays were due to the fact that the oil circuit breakers on the motor-generators were originally equipped with instantaneous undervoltage protection. Short-time dips in voltage on the power system caused some shutdowns so long as these instantaneous relays were in operation. These have now been replaced by relays having a time setting of two seconds, and no more delays of this nature have been experienced.

The power consumption of the main drives on the slabbing mill, over a period of six months of rather low tonnage operation, averaged 19.65 KW-hours per gross ton of sheared slabs. On the strip mill the main drive power over the same period averaged 61.68 KW-hrs. per ton. The power required by auxiliaries in the slabbing mill, including cranes and lighting, was 15.61 KW-hrs. per ton, and in the strip mill 27.24 KW-hrs. per ton. With increased tonnage output these figures unquestionably will be bettered.

The slabbing and strip mills and auxiliary equipment were designed and built by the Mesta Machine Company of Pittsburgh, Pa. The electrical equipment and steel work in #7 outdoor sub-station, the main driving motors, motor-generators, switchgear and control for the slabbing and strip mills and the majority of the auxiliary drives and control, with the exception of resistors, were supplied by the General Electric Company. The General Electric Company also installed the #7 sub-station and the slabbing and strip mill main drives. The drives for the flying shears, and the resistors for the majority of the auxiliary control were supplied by the Westinghouse Electric and Manufacturing Company.

A list of the auxiliary driving motors in the two mills follows:

Auxiliary Motors—45" Reversing Universal Slabbing Mill

Slab Shear Clutch—(1) 10 h.p., MD-404-AE, 800 r.p.m compound wound.

Vertical Spindle Shifter—(1) 10 h.p., MD-404-AE, 725 r.p.m., series wound.

Crop Conveyor Tilter—(1) 15 h.p., MD-404-AE, 650 r.p.m., series wound.

Slab Piler—(1) 20 h.p., MD-104, 725 r.p.m., series wound.

Left Hand Gate—(1) 20 h.p., MD-104, 375/725 r.p.m., series wound.

Right Hand Gate—(1) 20 h.p., MD-104,375/725 r.p.m., series wound.

Ingot Buggy (Dumping motion)—(1) 25 h.p., MD-408-AE, 575 r.p.m., series wound.

Shear Gauge Head Lift—(1) 25 h.p., MD-408-AE, 650 r.p.m., compound wound.

Shear Gauge Screw—(1) 25 h.p., MD-408-AE, 575 r.p.m., series wound.

Crop End Pusher—(1) 25 h.p., MD-408-AE, 575 r.p.m., series wound.

Shear Depressing Table Rollers—(2) 25 h.p., MD-408-AE, 575 r.p.m., series wound.

Shear Receding Table—(1) 35 h.p., MD-410-AE, 525 r.p.m., series wound.

Slab Piler—(1) 40 h.p., MD-105, 470 r.p.m., series wound.

Vertical Screw Adjuster #1 and #2—(2) 50 h.p., MD-412-AE, 500 r.p.m., series wound.

Slab Shear Approach Table—(1) 50 h.p., MD-412-AE, 500 r.p.m., series wound.

Crop Conveyor—(1) 50 h.p., MD-412-AE, 550 r.p.m., compound wound.

Ingot Buggy (Traverse motion)—(2) 75 h.p., MD-414-AE-2, 475 r.p.m., series wound.

Manipulating Fingers #1 and #2—(2) 75 h.p., MD-414-AE-2, 500 r.p.m., compound wound.

Slab Shear Main Drives #1 and #2—(2) 100 h.p., MT-562-Y-12-100-600, induction motors.

1st Approach Table—(1) 110/85 h.p., MD-107, 450/500 r.p.m., series wound.

Screwdown—(1) 150 h.p., MD-418-AE-2, 450 r.p.m., series wound.

2nd Approach Table—(1) 150 h.p., MD-418-AE-2, 450 r.p.m., series wound.

Entry and Delivery Table Rolls—(1) 150/200 h.p., MD-109-B, 375/425 r.p.m., series wound.

Right and Left Hand Side Guards—(2) 150/200 h.p., MD-109-B, 375/425 r.p.m., series wound.

Auxiliary Motors—Hot Strip Mill.

Oil Pumps—(2) 2 h.p., KT-934-1200 r.p.m.-220 volt, a-c.

Stack dampers on the Furnaces—(3) 2 h.p., BDE-43-A-1150 r.p.m., d-c.

Oil Pumps—(4) 3 h.p., KT-944-900 r.p.m.-220 volt, a-c.

Scale Conveyor—(1) 10 h.p., KT-502-900 r.p.m.-220 volt a-c.

Scale Breaker Clutch—(1) 10 h.p., MD-404-AE, 800 r.p.m., compound wound.

Furnace Table Stops—(3) 10 h.p., MD-404-AE, 725 r.p.m., series wound.

Scale Breaker Side Guard—(1) 10 h.p., MD-404-AE, 725 r.p.m., series wound.

Stop for Table beyond Shears—(1) 10 h.p., MD-404-AE, 725 r.p.m., series wound.

Screwdowns on #1 and #2 Stands—(2) 15 h.p., MD-406-AE-2, 650 r.p.m., series wound.

Edging Roll Adjusting Screws on Stands #3, 4 and 5—(3) 15 h.p., MD-406-AE-2, 650 r.p.m., series wound.

Oil Pumps—(4) 20 h.p., KT-522, 900 r.p.m., 220 volt, a-c.

Slab Turnover—(1) 25 h.p., MD-408-AE, 650 r.p.m., compound wound.

Tables between Stands #1, 2, 3, and 4—(3) 25 h.p., MD-408-AE, 575 r.p.m., series wound.

Loopers—(6) 35 h.p., MD-410-BF, 575 r.p.m., shunt wound.

Furnace Fans—(2) 40 h.p., KT-523-BA, 1800 r.p.m.-220 volt, a-c.

Furnace Approach Tables—(3) 50 h.p., MD-412-AE, 500 r.p.m., series wound.

Furnace Pushers—(6) 50 h.p., MD-412-AE, 500 r.p.m., series wound.

Screwdowns on Stands #3 to #11 inclusive—(9) 50 h.p., MD-412-AE, 550 r.p.m., compound wound.

Furnace Delivery Tables—(4) 50 h.p., MD-412-AE, 500 r.p.m., series wound.

Slab Transfer—(1) 50 h.p., MD-412-AE, 550 r.p.m., compound wound.

Mill Approach Table—(1) 50 h.p., MD-412-AE, 500 r.p.m., series wound.

Furnace Slab Transfer—(1) 75 h.p., MD-414-AE, 500 r.p.m., compound wound.

Edging Roll on #3 Stand—(1) 150 h.p. MDP-418-AE-2, 490/1250 r.p.m., compound wound.

Edging Rolls on Stands #4 and #5—(2) 150 h.p., MDP-418-AE-2, 450/1250 r.p.m., compound wound.

Scale Breaker—(1) 200 h.p., MT-566-Y, 600 r.p.m.-220 volt, a-c.

Blowers for Control House Ventilation—(2) 25 h.p., FT-503-1800 r.p.m.-220 volt, a-c.

High Pressure Pumps—(2) 350 h.p., TS-EL-1800 r.p.m.-280 KVA-6600 volt-1 PF synchronous motors.

Auxiliary Motors—Finishing End of Strip Mill

Cooling Bed Pinch Rolls—(1) 50 h.p.-MD-412-AE, 550/1100 r.p.m., shunt wound.

Up Cut Shear on Decoiler Shear and Table—(1) 40/57.5 h.p., MDP-412-AE, 530 r.p.m., shunt wound.

Plate Shear—(1) 100 h.p., MT-562-Y, 220 volt, a-c., 600 r.p.m.

Plate Shear Pinch Rolls—(1) 50 h.p., MD-412-AE, 550/1100 r.p.m., shunt wound.

Cooling Bed Transfer Tables—(2) 50 h.p., MD-412-AE, 550 r.p.m., compound wound.

Decoiler on Upcut Shear—(1) 40 h.p., MDP-410-AE, 565 r.p.m.

Slitting Shear—(1) 35 h.p., 651-T, 300/1200 r.p.m.

Leveler and Slitter—(2) 35 h.p., 651-T, 300/1200 r.p.m.

Cooling Bed Run-in and Run-out Tables—(3) 35 h.p., RF-16, 350/1400 r.p.m.

Cooling Bed Run-in and Run-out Tables—(4) 35 h.p., MD-410-AE, 575/1150 r.p.m., shunt wound.

Piler Receding Motion—(1) 35 h.p., MD-410-AE, 575 r.p.m., compound wound.

Coil Conveyor—(1) 35 h.p., MD-410-BF, 600/1800 r.p.m., shunt wound.

Scrap Baller—(1) 10 h.p., Frame 577-B, 1200 r.p.m., 220 volt a-c.

Squaring Shear—(1) 20 h.p., Frame 490-B, 1200 r.p.m., 220 volt a-c.

Mill Runout Table and Cooling Bed Run-in Table—(2) 35 h.p., RF-16-A, 350 r.p.m.

Recoiler—(1) 25 h.p., Frame 310-T, 400/1200 r.p.m.

Coiler Rolls—(5) 4.3 h.p., 110/440 volt, a-c., 300/900 r.p.m.

Coiler Pinch Rolls—(1) 10 h.p., 110/440 volts, a-c., 900 r.p.m.

Coiler Expander—(1) 2 h.p., 300/1800 r.p.m.

Copper Alloy Welding Rods†

By I. T. HOOK††

Scope of Paper

Copper and copper alloys have been prized for their beauty and utility for nearly 6000 years. Alloying as it does with some thirty of the ninety or more chemical elements, copper is one of the best known as well as the oldest of metals. This being the case, when we come to classify and describe those copper alloys carrying one or more additional elements, we would need a large volume for the purpose. It is necessary, therefore, to limit the scope of this paper to the copper alloys whose properties have been established as having considerable utilitarian value to the welder. Moreover, since we are interested for the moment chiefly in welding rods, or the deposited metal, we shall further confine our thought to the use of copper-rich compositions as the added metal, leaving out of consideration the copper alloy base metals except as they are incidental to the discussion.

Copper Alloys Included

While the following list of copper alloy welding rods is by no means complete, it is quite representative of the materials commercially available. The compositions given are those which we would normally expect but there is considerable variation in practice.

Only those properties in which the welder is particularly interested are given. Thus the tensile strength of most of the copper alloys can be doubled, sometimes tripled, by suitable cold work but the welder is interested in the strength of the metal in the weld an average value of which is given below.

The melting point of the welding rod enables the welder to select a metal which he can use without fusing a given base metal. The high value of the heat conductivity of copper explains almost wholly the difficulty in welding same. Silver which has a value of 1.000 in the c.g.s. units is the only familiar metal standing higher than copper in its heat conductivity capacity.

Melting Point		Heat Conductivity	Linear Coefficient of Expansion per Deg. C at low heats x 10^{-6}	Average Strength of Weld Metal lbs. per sq. in.
Deg. C	Deg. F	c.g.s. units		
Electrolytic or "Tough Pitch" copper .03-.07% oxygen, remainder copper + silver:				
1083	1981	.923	18.0*	15000 to 28000
Deoxidized Copper .01-.50% phos. or silicon or zinc or mn, etc., remainder copper:				
1083	1981	.30 to .90	18.0	30000 Max.
Common Brass 33-35% zinc, remainder copper:				
900	1652	.29	18.8	32000
Muntz Metal 40% zinc, remainder copper:				
885	1625	.30	19.5	35000
Tobin Bronze 38-40% zinc, .50-.75% tin, remainder copper:				
885	1625	.28	19.5	45000
Manganese Bronze 38-40% zinc, 1-1.5% iron, 0-1.5% tin, .03-1.25% mn, remainder copper:				
870	1598	.24	19.7	45000
Phosphor Bronze A 5% tin, .05-.50% phos., remainder copper:				
1050	1922	.20	17.0	38000
Phosphor Bronze D 10% tin, .05-.50% phos., remainder copper:				
1010	1850	.12	17.5	40000
Wrought Nickel Silver 18% nickel, 27% zinc, .05-.15% mn, remainder copper:				
1055	1931			35000
Extruded Nickel Silver 8% nickel, 40% zinc, 2% mn, remainder copper:				40000
Ambrac: 20% nickel, 5% zinc, .50% mn, remainder copper:				
1150	2102	.09		30000
Monel Metal: 67-70% nickel, 2-4% iron+manganese, remainder copper:				
1360	2480	.06	14.3	
Everdur: 3% silicon, 1% mn, remainder copper:				
1020	1868	.078	18.0	50000
Brazing Solder, golden: 50% zinc, remainder copper:				
868	1594	.43		42000
Brazing Solder, white: 50% zinc, 10% nickel, remainder copper:				
895	1643			40000
High Phosphorus Copper: 1-8% phos., remainder copper:				
710	1312	.11 at		22000 to
1070	1958	1% P		32000
Silver Solder: 20-80% silver, 0-30% zinc, 0-2% nickel, 16-60% copper:				
700	1292			
927	1700			
Common Steel: .05-.20% carbon, .45% mn, .045 max. for S and P:				
1530	2786	.12 to .14	11.7	50000
Gray Cast Iron: 3-3.5% carbon, 1.25-3% silicon, .05% max. S, .30-1.5% P, .10-1% Mn:				
1230	2246	.07	8.4	22000 to 28000

Detrimentals

It will be noted that we have left out of the above list two very common elements which are

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† Presented before A. I. & S. E. E. Electric Heating and Welding Conference, Pittsburgh, Pa., January 21, 1931.

* = 24.6 is an average up to m.p.

frequently seen in copper alloys, viz, aluminum and lead. As is well known, aluminum in amounts up to 12% forms with copper a very useful high-strength, corrosion-resisting series of alloys having a beautiful bronze yellow color. Its corrosion-resisting qualities arise largely from a thin film of infusible, closely-adhering, tough oxide. Even small amounts of this oxide make the molten metal flow sluggishly, insulating it from the heat and preventing its adherence to a base metal. It is not readily dissolved by the borax base fluxes as are the other copper alloy oxides.

Lead is objectionable for a different reason. It is practically insoluble in solid copper. Hence while it is frequently used in copper alloy bearing metals in amounts up to 15% or 20%, it is a detrimental from the welders standpoint because in the first place, it makes a heterogeneous mixture. Moreover, it melts at a comparatively low temperature, 327°C (620°F) and oxidizes readily at the temperature of melting copper not only causing lead oxide in the weld metal but also making the latter porous. It should not be present in a welding rod in amounts in excess of .05% to .08%.

Welding Properties

The properties of welding rods of universal interest to the welder are (1) melting point, (2) volatilization or boiling point, (3) heat conductivity, (4) coefficient of expansion, (5) flowing qualities, (6) soundness of weld metal, (7) strength of weld metal, (8) toughness or ductility of weld metal, (9) avidity with which it will alloy with the base metal, (10) by what processes it can be applied, (11) appropriate flux, (12) appearance of finished weld.

The welder may also be interested in the following attributes of the weld metal:—(13) color match with base metal, (14) resistance to wear of weld metal, (15) electrical conductivity, (16) effect of cold work on weld metal, (17) the principal applications of the alloy in question.

These properties are discussed below for each alloy. Common steel and gray cast iron are included for the sake of comparison, their widespread use as base metals making them familiar to every welder.

Detailed Properties

Low carbon steel has long plastic or weldable range before it melts, has excellent ductility both hot and cold, can be welded by any process, has good strength and soundness. It is applicable only to steel base metal—its melting point being too high for use with the copper alloy base metals or cast iron.

Cast iron:—Unlike steel, cast iron is not ductile hot or cold. Lacking the plastic range of steel, it can not be pressure welded as can the latter. It must, therefore, either be fusion welded or brazed by a lower melting alloy while it is itself rigid. The copper alloys adhere to cast iron with remarkable tenacity when the mechanical interference of the graphite constituent of the base metal is properly taken care of. (See notes on Tobin Bronze).

Electrolytic or Tough Pitch copper will lie quiet at a dazzling white heat. It has the highest heat transfer capacity of any material available generally to industry. Incidently, it is this property that makes the welding of this metal (used as a base metal) so difficult—it must be heated red hot some considerable distance back from the weld in order to attain a melting temperature at the desired point. In general, we must use **more** heat for welding copper than for welding steel though the actual intensity (temperature)need not be so great. The soundness and strength of the weld metal depend largely on how it is applied. If conditions are such that there is no great increase in the oxygen content (.03% to .07%) nor yet a complete reduction of the cuprous oxide, we should obtain a sound weld metal having a strength of the order of 28000 lbs. per sq. in. With the welding methods in general use, there is apt to be an objectionable increase in the amount of bulky cuprous oxide as the metal is flowed into place which in general means a loss of both strength and ductility. On the other hand, if precautions are taken to flow the weld metal is a reducing atmosphere, the cuprous oxide is reduced to pure copper and the molten weld metal then is prone to take up some of the reducing gas, usually hydrogen or carbon monoxide, rejecting it again when freezing, entrapping thereby numerous blowholes which reduce the strength of the weld metal.

Tough pitch copper is for the most part quite ductile. It can be rolled, hammered and drawn in to the thinnest of sheets and the finest sizes of wire cold. It is also quite malleable when hot with the exception of a short temperature range immediately under the melting point when the cuprous oxide breaks down.

It will weld to steel, cast iron, nickel, Monel metal, developing in the bond from 15000 to 28000 lbs. per sq. in. depending upon the method of welding. It can, of course, be used to weld copper base metal. It works best with the oxy-acetylene torch though it can be applied by the metal arc, the carbon arc, the muffle furnace, etc. It is not recommended as a welding metal except where it is to be used in a thin film or where the strength requirement is not great. Deoxidized copper will usually work so much better that the slight additional cost is more than justified. There are times, however, when in overhead welding the tough pitch copper will be preferred to deoxidized copper as it is less fluid than the latter.

Deoxidized copper:—The melting and boiling points of deoxidized copper are slightly lower than those for electrolytic copper depending upon the amount of deoxidizer used. The actual requirement to take care of the .03% to .07% of oxygen is extremely small but the deoxidizer is usually added in quantities sufficient to take care of the welding oxides. Hence if phosphorous, silicon, manganese or zinc is employed for this purpose from .05% to .50% is present in the welding rod. The amount of deoxidizer left in the weld metal will be smaller than this depending upon how severe the oxidizing conditions were during the welding operation.

Deoxidized copper has nearly the same heat conductivity, coefficient of expansion and flowing qualities of copper. The weld metal containing no oxides and being less likely to dissolve gas than pure copper usually comes down much sounder. It is, therefore, decidedly easier to obtain the full strength of dead soft copper—about 30000 lbs. per sq. in.—than is the case with electrolytic copper. The toughness and ductility of the weld metal cold is approximately the same as that for pure copper but the deoxidiza-

tion results in an improvement of the hot working properties.

The deoxidization also results in a lower electrical conductivity and to a similar extent lower heat conductivity. Thus a copper carrying .034% phosphorous has an electrical conductivity of 80% I. A. C. S. Another carrying .043% silicon has an electrical conductivity of 86% and a third copper carrying .075% manganese has an electrical conductivity of 91% I. A. C. S. while a copper carrying .51% zinc has an electrical conductivity of 92% I. A. C. S. and a heat conductivity of 92% as great as that of pure copper.

Deoxidized copper weld metal finds its greatest application in the welding of electrolytic or deoxidized copper base metal where an autogeneous weld is desired. Considerable quantities of silicon deoxidized copper welding rods are used in rail bonding and other places where a reasonably good electrical connection is desired along with sufficient strength to keep the connection intact. In this case the electrical conductivity is approximately 40% I. A. C. S.

It is also used for tacking together the sheet steel used in the manufacture of metal furniture. The advantage here lies in the fact that it flows freely onto the steel sheet at a temperature that enables the operator to avoid the hazard of burning holes through, while it has sufficient tenacity to hold the parts together at the enameling heat. No flux is required, which facilitates the cleaning of the assembled article for final enameling or finishing. Everdur is used for the same purpose and has the advantage of greater strength.

Copper alloys do not combine with carbon as does steel. Hence deoxidized copper can be readily welded with the carbon arc securing thereby a somewhat smoother finish than can be obtained with the metal arc. The carbon electrode has recently been adapted to the automatic arc welding machines which facilitates greatly the welding of long seams—the rod being laid on the seam and fused to the base metal.

Common brass: Common brass flows quite freely and will adhere readily to steel, other copper alloys, and to a less extent, cast iron. It is occasionally used for welding brass where a color match is desired but in general, Tobin Bronze, by reason of its freer flowing qualities, lower melting point, and higher strength and soundness, is preferred.

The zinc constituent which boils at 918°C* (1684°F) and ignites in the presence of air at a much lower temperature, makes the application of this material by the metal arc or the carbon arc impractical.

Muntz Metal: Muntz Metal (sometimes called "brazing metal") flows freely in all respects similar to Common Brass with the exception that its melting point is slightly lower. It is sometimes used as a low cost brazing rod but as is the case with Common Brass, Tobin Bronze is to be preferred for all other considerations.

Tobin Bronze: This alloy was discovered by Lieutenant John H. Tobin of the U. S. Navy in 1876, the same year that Parsons in England brought out Manganese Bronze. It has remarkably good flowing qualities when used with the oxy-acetylene torch, its melting point being low enough so that most other copper alloys, as well as cast iron and steel, can be welded with this rod without the base metal itself being fused. It has excellent ductility, both hot and cold, comes down as a sound, fine-grained weld metal having a strength very nearly the maximum of the copper-zinc-tin alloys. It alloys avidly with other copper metals and steel developing nearly the full strength in every case. It is perhaps the best alloy we have for welding cast iron, the only precaution that need be taken being that of freeing the surface of the base metal from the graphite which is usually smeared thereon by machining or grinding process. This can be done by the sand blast or by annealing in a partially oxidizing atmosphere. The weld metal has good wear resistance as well as ductility.

Tobin Bronze is most frequently applied with the oxy-acetylene torch, the zinc content being too high for use with the electric arc.

It has found a wide range of applications, from the welding of large sections such as cast steel locomotive frames to the joining of delicate parts of instruments. Applied to cast iron pipe, it makes a much more economical and tighter connection than the heavy, leaded bell joint so familiar in water and gas mains. It is equally applicable to smaller pipe in steel and red brass, rendering the use of threaded connections unnecessary.

The ductility of the weld metal is such that when applied to cast iron at a cherry red heat, the cooling strains will be absorbed by the bronze making preheating, such as would be required in using cast iron weld metal, unnecessary. Thus it is an aid to economy not only in the saving of preheating but by reason of its application at a low heat as well.

Manganese Bronze: The flowing qualities of Manganese Bronze are in all respects quite similar to those of Tobin Bronze. The strength is also nearly the same but the ductility is if anything, slightly lower with a slightly higher wear resistance and a somewhat lower impact resistance. In general, Manganese Bronze does not have quite the soundness of Tobin Bronze weld metal. Its applications are very nearly the same as those for Tobin Bronze, but owing to the variety of mixtures being sold under the general name "Manganese Bronze," we are not as confident of the results obtainable as is the case with the former.

Phosphor Bronze A: The Phosphor Bronze A is a modern successor to the bronze of the ancients, carrying 5% tin. It is usable with other copper alloys, with steel and with cast iron. It can be applied with either the oxy-acetylene torch or the electric arc. When used on other copper alloys, a fusion weld results, but in the case of cast iron or steel base metal, it melts at a sufficiently low temperature so that the latter need not be fused. It has good wear resistance though somewhat inferior in this respect to the 10% tin Phosphor Bronze D.

The metal cold has excellent ductility but hot it is not quite on a par with Tobin Bronze. The same is true of the soundness of the weld metal. Its only advantage over the latter is that it can be laid down by the electric arc. It is entirely practicable to flow Phosphor Bronze on galvanized iron using the carbon arc without burning off the zinc coating on either side of the weld. Phosphor Bronze alloys more avidly with the brasses than most of the high

* = Boiling point of pure zinc. As it occurs in brass and bronze alloyed with copper, the boiling point is much higher.

copper welding rods. Thus commercial bronze and red brass can be welded with this alloy using any method of welding. It closely matches the color of commercial bronze and is a paler red than pure copper.

Phosphor Bronze D: This alloy has somewhat greater strength and lower ductility than the above Phosphor Bronze A. It melts at a somewhat lower temperature and flows more freely. It can also be used with any method of welding. It approximates very nearly the famous "gun metal" of the days when battles were won or lost by the weight of the bronze cannon available. It is prized for its cast strength, beauty of color and excellent wear resistance, being frequently used for building up worn steel pins or cranks.

Wrought Nickel Silver: This alloy, carrying 18% nickel, can be obtained as a base metal in sheets and is used a great deal for the manufacture of soda fountains, kitchen fixtures, doors, window frames, sash, grill and similar ornamental work. As a welding rod, it is used principally for welding the base metal, obtaining thereby a good color match and fair strength. It is recommended for use with the oxy-acetylene torch only, though there have been recent developments where the carbon arc is being used.

Extruded Nickel Silver: This material is somewhat lower in melting point and is less inclined to hot shortness than the wrought nickel silver above. It provides an alloy which can be applied by means of the oxy-acetylene torch to cast iron or steel giving a fairly good color match thereto and it can be used with other nickel silver base metals where a good color match with free flowing qualities of weld metal are desired.

Ambrac: This metal is somewhat similar in appearance to the nickel silvers above and has the advantage of the two nickel silver welding rods in that it can be used with the electric arc either as a metal arc electrode or with the carbon arc. Most of the 5% zinc burns out in an arc welding operation but does not impair seriously the soundness of the weld metal. It can be used on cast iron or steel as well as the white copper alloys giving a fairly good color match thereto.

Monel Metal: As a base metal, this material has very nearly the same color as the Nickel Silver and Ambrac but by reason of its higher nickel content it has somewhat greater strength, and springiness than the former. As a welding rod, it can be used either with the torch or the arc. Like the Phosphor Bronzes above, it is inclined to be hot short and should be protected by a suitable flux. It is used principally with Monel Metal sheets and shapes and for welding on cast iron or cast steel with the electric arc.

Everdur: Everdur is a fairly recent addition to the copper alloy series, having been patented by Mr. Charles B. Jacobs May 26, 1925. It has perhaps the highest place among the copper alloys in the facility with which it can be welded. Used as a welding rod, it can be applied with any method, yielding strong, sound weld metal which has excellent ductility. A narrow region of hot shortness immediately under the melting point calls for caution on the part of the welder in cases where shrinkage is taking place as the weld metal passes through this range. When cold, its ductility compares favorably with that of the best Swedish iron and can be cold worked to a considerable extent increasing its strength and hardness. As a base metal, it has come into great popularity for range boilers, tubes, and containers where high corrosion resistance or non-magnetic properties combined with high strength are required.

While most of the Everdur welding rod is used on a similar base metal, it has found wide use. It can be applied to steel by the metal arc process developing very nearly the full strength of the latter. On sheet metal furniture, it has replaced to a large extent deoxidized copper for tack welding the sheets together. It can also be used in welding copper making a stronger joint than can be obtained with the copper rods.

In color it resembles the pale red of the gun metal bronze.

Brazing solder, golden: This material has the lowest melting point of any of the alloys in the copper-zinc series which are commercially available. It is a hard, strong metal which has very little ductility and can be hammered into fine powder. It is frequently used in the powdered form mixed with flux and fused into a lapped or scarfed joint in other copper alloys running in between the surfaces and alloying avidly with the base metal to form a strong joint. Used in this manner its ductility is improved by its alloying with the base metal and by a slight loss of zinc.

Brazing solder, white: This alloy is very similar in action to the yellow brazing solder except for its white color. It would be used, of course, in place of the former where a color match is desired between a white base metal and the solder.

Silver solder: There is a great variety of silver solders, all of them containing silver in some proportion between 20% and 80%. The silver added to the copper and zinc has the effect of lowering the melting point, aiding in the free flowing qualities without its being susceptible to volatilization as is zinc. It also promotes soundness in the weld metal. It is used in place of the brazing solders where greater ductility is desired as for instance, in the joining of copper or copper alloy rods which are later to be drawn into wire. A silver soldered joint will stand a severe deformation of wire drawing where rods, sometimes ¾" in diameter, are drawn into fine wire sizes. It is also occasionally used where the melting point of a brazing solder would be found too high.

All of the silver solders are white though when the silver content is low, they are apt to have a yellow cast. Owing to the cost of this material it is usually employed on lap joints where a thin film only is needed.

Flux: With most of the copper alloys a flux is found necessary to free the weld metal from the oxides which are formed and to promote the free flowing qualities and aid in the smoothness of the finished weld. Since all of the copper alloys melt at 1300°F. or above, borax which melts at a red heat is the base for nearly all of these fluxes. Borax will take up nearly all of the copper oxides. Additions are frequently made of zinc chloride, ammonium chloride, sodium chloride, the two former melting at a lower temperature than the borax, which aid in preventing the oxidation of the base metal in the pre-red temperatures. The chlorides also act as

cleansers for the base metal. Boric acid is frequently used to dilute the borax, diminishing somewhat the amount of hard borax glass left on the weld.

Common borax may be used but it has the undesirable quality of crawling away from the heated surface when it gives up its water of crystallization before arriving at its melting point. This permits the weld surface to be exposed to the flame or the air. If, however, the borax is first melted into a borax glass and then reground into a flour-like powder, it may be used on the weld as dry powder or mixed with absolute methyl alcohol into a thin paste. Under these conditions, it will melt quietly without shrinking from the heat or exposing the weld surfaces.

In the case of cast iron where we have the graphite appearing on the weld surface, the addition of an oxidizing element such as manganese dioxide, cuprous oxide or potassium chlorate is beneficial for aiding in tinning the metal. After the metal is thoroughly tinned, it is better to use a non-oxidizing flux such as fused borax, or a mixture of the latter with boric acid, for the balance of the weld metal.

In the case of Everdur, little or no flux is required though a light coating of 90% fused borax plus 10% sodium fluoride promotes the free flowing qualities of the metal. The sodium fluoride constituent aids in the softening of the very resistant silicon oxide.

Applications

The copper alloys used as base metals form a very much larger and more complex series than the seventeen alloys quoted as weld metals. And the particular weld metal to use in a given case depends very largely upon the strength of connection desired, the melting point of the base and weld metals, the ductility and aesthetic qualities desired, and the method of application. In general, those weld metals having a zinc content greater than 5% are not usable with arc welding methods but must be applied with the torch. On the other hand, those alloys of copper and tin, copper and nickel, copper, silicon and manganese can be applied with the electric arc.

A large proportion of these metals are used for architectural purposes and as such a color match is very often desired. Again, they are frequently used where corrosion resistance is an item, in which case a weld metal similar to the base metal is the best answer to resistance to electrolytic action.

Since all of these welding rods melt at a lower temperature than steel or cast iron, they are often found economical to use though the cost is several times that of similar welding rods in the ferrous metals.

There is usually one best rod for a given purpose and to select that rod calls for a more or less intimate knowledge of the rather complex list of copper alloys. It is usually preferable, therefore, for the average welder to consult a copper alloy manufacturer than to arrive at the goal by the time-consuming and oft times expensive method of cut and try.

Acknowledgement: The International Critical Tables and Bureau of Standards Technical Papers #410 and #426 were consulted freely in securing values of the melting points and coefficients of expansion. Nearly all of the heat conductivities were measured by Dr. Cyril Stanley Smith in the Laboratory of The American Brass Company, while the values for tensile strength were also taken from the records of this Laboratory.

Items of Interest

PERSONNEL CHANGES

Albert L. Cromlish of Farrell has been appointed general superintendent of the Duquesne plant, Carnegie Steel Company, succeeding Samuel G. Worton, resigned. Mr. Cromlish has been superintendent of the Farrell works since 1920.

Harry L. Brindle, assistant general superintendent of Farrell works, Carnegie Steel Company, Pittsburgh, has been made general superintendent to succeed A. L. Cromlish, recently transferred to Duquesne works. Mr. Brindle joined the Carnegie Steel organization in 1917.

F. H. N. Gerwig, assistant superintendent of blast furnaces at Edgar Thomson works, Carnegie Steel Company, Pittsburgh, since November, 1913, has been appointed superintendent of blast furnaces, to succeed the late A. C. Maccoun.

J. C. McQuiston, general advertising manager of the Westinghouse Electric and Manufacturing Company has retired after 29 years spent as head of the Westinghouse advertising department.

M. B. Lambert, assistant to the vice president, Westinghouse Electric and Manufacturing Company, East Pittsburgh Pa., will take over the general direction of advertising in addition to his other duties.

E. O. Sessions, head of the Sessions Engineering Company, Chicago, has accepted the invitation of the Soviet Government to visit Russia for the purpose of making a survey of the industrial situation in that country and a general study of the five-year plan. He is now en route to Moscow.

Albion Bindley, associated with Pittsburgh Steel Company, Pittsburgh, for a number of years will succeed Robert McMillan, purchasing agent for the past 20 years, who retires July 1.

Tom J. Muir, assistant sales manager for the last three years of Morgan Engineering Company, Alliance, O., has been appointed director of sales. He has been connected with the company for 29 years in various capacities, 24 of which were spent in the sales department.

A. T. Davis has been made sales manager. He has been identified with the company for 19 years, the last 12 of which he has been in the sales department.

T. W. Jenkins has been appointed superintendent of the Monroe, Mich., plant of Newton Steel Company, Newton Falls, O.

Charles Gross, who has been superintendent of the South Side, Pittsburgh, works of the A. M. Byers Company, has been appointed general superintendent of the company's Economy, Pa., plant, succeeding C. W. Edwards, who has resigned. Mr. Gross has been identified with the Byers company

during his entire business career, having succeeded his father in the position he has held recently.

Amos Kamerer who has been pipe mill superintendent at the South Side plant, succeeds Mr. Gross as general superintendent at the same works.

Harry T. Gilbert, formerly vice president in charge of sales for the Republic Steel Corporation at Youngstown, O., and recently special assistant to the president, with offices at Cleveland, resigned last week. Prior to going with Republic in 1928, Mr. Gilbert had been associated with the Sharon Steel Hoop Company, Sharon, Pa., being vice president at the time of his resignation. For the present, Mr. Gilbert will take a vacation.

Gordon Fox and W. S. Orr, members of the engineering staff of the Freyn Engineering Company arrived in the United States June 19 on the S.S. Vulcania. Mr. Fox and Mr. Orr have been in the U.S.S.R. for the past ten months in connection with consultation services which Freyn-Engineering Company is rendering to the Soviet iron and steel industry.

A. H. Dyckerhoff, a member of the Association of Iron and Steel Electrical Engineers, recently returned from a trip to Germany where he was awarded a degree of doctor of engineering, with highest honors, from the University of Berlin, Charlottenburg. This is the first time a graduate of the institution has been honored with this degree after practicing engineering for many years in the United States.

Dr. Dyckerhoff's work with the Commonwealth Edison Company, The Peoples Gas Light and Coke Company, Public Service Company of Northern Illinois and Northern Indiana Public Service Company pertains mainly to special problems mutually affecting the gas and electric utilities and the iron and steel plants of the Chicago district.

R. D. Bean, formerly Manager of the Engineering Development Department of The Brown Instrument Company, Philadelphia, has been made Chief Engineer of that company. Mr. Bean's extensive field investigations covering many applications of Brown industrial measuring instruments have won him wide acquaintance and his numerous friends will be glad to hear of his promotion.

Mr. K. A. Daugherty has been made assistant superintendent, electrical department of the National Tube Company, Gary works. His former position was general foreman, electrical department.

F. F. Eillott has been appointed mill and foundry general superintendent of the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

H. F. Seifert has been appointed superintendent of the brass foundry and copper mill.

C. R. Stevens has been named purchasing engineer of the purchasing department.

George W. Nelson, formerly assistant superintendent of the Clinton, Mass., plant of Wickwire Spencer Steel Company, New York, and Worcester, Mass., has been appointed superintendent to succeed Francis N. Woodman, who has resigned after filling that office for the past four years.

George G. Crawford, president, Jones and Laughlin Steel Corporation, Pittsburgh, on June 8 was awarded a doctor of science degree by Georgia School of Technology. He was graduated from that institution in 1890 with a bachelor of science degree in mechanical engineering.

The Trumbull Electric Manufacturing Company, Plainville, Conn., wishes to announce the appointment of Mr. W. J. Batchler as salesman covering the District of Columbia, Maryland, Virginia and North Carolina in place of Mr. F. G. Marden who has resigned.

George B. Karelitz has been appointed acting manager of the mechanics division of the Westinghouse Research Laboratories, to fill the vacancy caused by the recent promotion of John M. Lessells to the South Philadelphia Works of the company.

The appointment was made by L. W. Chubb, director of the research laboratories, and announced by S. M. Kintner, vice president in charge of engineering.

At a recent meeting of the board of directors of the Westinghouse Electric and Manufacturing Company, J. S. Tritle was elected vice-president and general manager in charge of manufacturing, sales and engineering operations of the Company, reporting to the president F. A. Merrick.

The Holophane Company, Inc., 342 Madison Avenue, New York City, announces the appointment of A. D. Cameron as Manager, effective June 1st.

Mr. Cameron was formerly active in the lighting field as manager of the lighting and supply division, central station department, General Electric Company, Schenectady, N. Y.

Mr. D. J. Quammen has been appointed manager of the Philadelphia district office of Cutler-Hammer, Inc., manufacturers of electric motor control and allied apparatus, whose headquarters are at Milwaukee, Wis. Mr. Quammen succeeds Mr. F. J. Burd, who has been made assistant manager of the Chicago office of Cutler-Hammer. Mr. Burd will have charge of industrial sales in the Chicago district, and of the C-H (Harland) paper machine drive, throughout the country.

A. D. Hunt, former manager of engineering at the South Philadelphia works of the Westinghouse Electric and Manufacturing Company has been transferred to that company's Chicago office.

Mr. Hunt will be engaged in the company's steam apparatus activities in the western districts.

Arthur G. McKee & Co., engineers and contractors, Cleveland, announce the appointment of Gray I. Morriss as sales engineer with headquarters at the eastern office of the company at 120 Broadway, New York City.

G. L. Harris has been appointed manager of office systems of the Westinghouse Electric and Manufacturing Company, it is announced by President F. A. Merrick.

The appointment of J. M. Hipple as general works manager for the Westinghouse Electric and Manufacturing Company has been announced by J. S. Tritle, vice president and general manager. C. H. Champlain, manager of the Westinghouse works at Sharon for the last eight years, succeeeds Mr. Hipple as works manager at East Pittsburgh.

Mr. Hipple has been works manager of the East Pittsburgh works since September 1, 1927.

Mr. Tritle also announced the appointment of M. L. Fawcett as works manager at Sharon.

Mr. Tritle announced that A. B. Reynders, in addition to his present duties as works manager at East Springfield, Mass., will have supervision over

the operations of the Mansfield works, and that J. E. Barkle will have supervision over the Newark works in addition to his duties as works manager at South Philadelphia. E. M. Olin, works manager at Mansfield and H. E. Miller, works manager at Newark, retain their present positions reporting to Mr. Reynders and Mr. Barkle respectively.

WITH THE MANUFACTURERS

Lukenweld, Inc., (division of Lukens Steel Company, Coatesville, Pa.) has appointed the Dravo Doyle Company as representative in the Pittsburgh territory, and W. R. McDonough and Company as representatives in the Cleveland district. Lukenweld, Inc., is engaged in the design and manufacture of parts of machinery and equipment by gas-cutting, forming and arc welding of rolled steel.

The Benjamin Electric Manufacturing Company, Des Plaines, Ill., has published their bulletin, No. AD 2785, describing and illustrating their new Floodlight Projectors for floodlighting buildings, yards, monuments, outdoor sport areas and other locations. The bulletin may be secured by writing to the general offices or any of the branch offices of the Company.

A 16-page publication entitled, Westinghouse Arc Welding Data Bulletin No. 15, has recently been announced. This booklet contains illustrations of many unusual arc welding achievements, explains with the aid of diagrams various methods of testing, and discusses methods for obtaining good welds.

Copies of this publication (D.M.F. 5350) may be obtained from the nearest Westinghouse district office or directly from the advertising department, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

The Trumbull Electric Manufacturing Company, of Plainville, Conn., announce that New Catalog No. 15 and supplementary bulletins, giving complete description of all Trumbull products are now being distributed. Copies are available upon request.

Horizontal planes may be quickly and accurately leveled in all directions simultaneously by using the new Universal Level, which National Electric Products Corp., of Pittsburgh, Pa., are now manufacturing. Designed for leveling where height adjustments were to be made in installing floor distribution systems, this level is very useful in workshops, homes and offices. It can easily be carried in the pocket as it measures only 4½" at the widest point and is 1" high.

"Shallcross Controls" is the title of a new loose leaf catalog brought out by the Shallcross Control Systems Company of Milwaukee, Wis. From time to time new sheets will be published and old sheets revised thus keeping the catalog up to date. Copy of the catalog may be had by writing the above company.

The United States Graphite Company of Saginaw, Michigan are distributing a well illustrated catalog entitled "Carbon Products." This 40-page catalog contains many interesting and instructive facts on Brushes and Carbon Products. Interested parties may obtain copies by writing for Catalog No. B-5.

H. O. Swoboda, Inc., Pittsburgh, Pa., are disttributing the new Bulletin No. 260 which supersedes Bulletin No. 190 on "Falcon" continuous electric furnaces for heat treating strip metal and wire. Copies may be obtained by writing the above company.

Leaflet 2135 entitled "Frog Leg" Armature Windings is now being distributed by the Allis-Chalmers Manufacturing Company of Milwaukee, Wis. To secure copies of this leaflet write the above company.

Bulletin No. 94 describing Wellman Open Hearth Charging Machines is now ready for distribution. Copy of this sixteen page, well illustrated bulletin may be had by writing Wellman Engineering Company, Cleveland, Ohio.

Bulletin No. 209 on Type T Heavy-duty Reliance Motors for Direct Current is just off the press. It is an attractive 32 page bulletin well illustrated with photographs and drawings and copy may be obtained by writing Reliance Electric and Engineering Co., Cleveland, O.

The Detroit Lubricator Company of Detroit, Michigan are distributing their Catalog No. 185 which explains the design and operation of their Model B Locomotive Mechanical Lubricators. Copy of this catalog is available to interested parties.

THE BROWN INSTRUMENT COMPANY PUBLISHES CATALOG FEATURING ITS NEW POTENTIOMETER PYROMETER

The Brown Instrument Company, Philadelphia, Pa., has published a new Catalog No. 1101 featuring a new line of potentiometer pyrometers recently introduced by this company. The catalog is a 48-page book well illustrated. It contains a short introduction outlining the nature and field of the potentiometer principle as applied to pyrometry, shows how this principle is incorporated in the new Brown Potentiometer Pyrometer, and follows this with a concise description of more than fifty features. Many of these features are exclusive. All are novel and interesting. The instrument has a broad application to industrial needs involving the measurement and control of temperatures especially in the higher ranges. Copy of this catalog will be sent to any executive by The Brown Instrument Company, Philadelphia, Pa.

"SIMPLEX" SYNCHRONOUS MOTOR PUBLICATION

The new Type HR "Simplex" Synchronous Motors are described in Leaflet 20519, recently published by the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa. These motors, which are designed for driving low-speed, constant-sped machinery where low starting current combined with high starting and pull-in torque is required, are discussed in this leaflet from application, construction, and operation standpoints. The leaflet is illustrated with photographs, drawings, and curves.

THE NEW ERIE HOOK-ON BUCKET

The Erie Steel Construction Company, of Erie, Pa., wish to announce that they now manufacture a Hook-On or Single Line type of clamshell bucket. With the addition of this new unit they now manufacture a type and size bucket for every kind of digging and material handling.

They state that the new Hook-On Bucket is improved in design which gives it from 10 to 25% more closing power, thus making it valuable for more efficient digging on a wider range of work. This

bucket is instantly available for work on cranes by placing the bucket yoke on the crane hook. Therefore, it is only necessary to tie-up the crane for the length of the bucket job.

Complete operation of the bucket is carried on from the crane cab. The action of the bucket is quick and positive, and it is safe because the latching mechanism cannot accidentally become disengaged, thereby discharging the load.

The closing line is reeved around snubber sheaves, eliminating serious opening shock, and when the bucket is fully open the power arm comes to rest against heavy bumper springs which act in combination with the rope reeving to give a smooth opening bucket.

The Erie Steel Construction Company will be pleased to send circulars describing and illustrating the new bucket.

BROADENING THE FIELD OF RECORDING INSTRUMENTS

Recording instruments such as voltmeters, ammeters, etc., have always been less sensitive than corresponding indicating instruments, the results of the mechanical burden placed upon the instrument by the recording pen. The inertia of such a weight has made it impossible for a recording instrument to respond as quickly or to as small a quantity as could an indicating instrument.

Now, by the application of a different principle, the General Electric Company has produced recording instruments of increased sensitivity and accuracy. A beam of light has no weight, so, by incorporating photoelectric and pliotron tubes, in recording instruments, it has been made possible to record quantities where only a limited amount of energy is available.

In the Photoelectric Recorder the inking pen is driven by a small high-torque element supplied from an auxiliary source of energy. Directly beneath the recording element is an indicating instrument element that is operated by the quantity which is to be recorded. A photoelectric circuit and an optical system of special design cause the recording element to follow the indicating element and make a continuous record of the deflection. In this manner any quantity which may be indicated can also be recorded.

The only mechanical burden placed upon the indicating element is a tiny galvanometer mirror. For ordinary applications, miniature indicating instrument elements are entirely satisfactory, and result in a minimum energy requirement from the circuit which is being measured. The instruments can be of the most sensitive types.

The photoelectric circuit and optical system represent a distinct departure from past practice. Errors due to ordinary variations in supply voltage, photoelectric and pliotron tube characteristics, lamp intensity and other variables usually troublesome in such circuits have been practically eleminated. The filaments of the various tubes are operated at voltages well under their rating, insuring long life.

The energy taken from the measured circuit is extremely small, being only that amount necessary to operate the indicating element. Recorders can readily be constructed with a full-scale deflection of 20 microamperes, at which current the power requirement from the measured circuit is less than one microwatt. On the other hand, there is no upward limit to the rating of the indicating element; the recorder is adapted to almost any type of service conceivable in measurement work.

The recorders now available can be obtained incorporating practically any of the General Electric indicating instruments.

Surface Combustion Corporation announce the closing of contracts with the Granite City Steel Company for three Continuous Pack and Pair Furnaces to be installed on their tin mills. The furnaces will be of the Walking Beam type having two rows operating independently with full automatic discharge features. Firing is over and under with natural gas.

Granite City Steel has placed in operation two Continuous Pack and Pair Furnaces on the sheet mills at North Works, which were built by Surface Combustion. This new contract, however, covers the first furnaces of this type to be installed on tin mills.

Surface Combustion Corporation has also recently contracted to install the Tube Normalizing Furnace in the plant of the National Tube Company at McKeesport, Pennsylvania.

This furnace will use coke oven gas for fuel and will maintain a temperature of approximately 1650° F. The maximum capacity of the furnace will be 44,800 lbs. per hour and it will treat tubes up to 48′ in length and 18⅝″ in diameter.

P. & H. ANNOUNCES A NEW ONE YARD EXCAVATOR

A new improved, full revolving one yard excavator, known as the P&H Model "500," is just announced by Harnischfeger Corporation. This machine, which spent the winter" working in the test field is now being put into production to be ready for delivery at a very early date.

The "500" follows the general proven P&H design with a number of added refinements. Main frames are unit alloy steel castings. Wearing parts are of alloy heat treated steels. Drums are in tandem and operate through the P&H power clutch control. A minimum number of gear reductions makes this new machine extremely simple. Sturdy gasoline, Diesel, or electric motors provide ample power whether the machine is used as shovel, dragline, crane, clamshell, hoe, or skimmer.

A bulletin describbting the P&H Model "500" may be obtained by either writing to the Main Office of Harnischfeger Corporation at Milwaukee or to any branch office.

NEW BOOKLET ON MAGNETIC CLUTCHES

"Keeping Pace with Machine Design" is the title of a new booklet just published by Cutler-Hammer, Inc., Milwaukee, Wis.

The booklet details the construction, operation and application of C-H Magnetic Clutches, including a full description of the newly developed C-H Duplex Clutch. There are many installation photographs showing magnetic clutches applied to various types of machines. The schematic diagrams which demonstrate the action of the clutches are instructive and interesting.

A copy of "Keeping Pace with Machine Design" will be sent free upon request to Cutler-Hammer, Inc.

NEW ALLOY DEVELOPED

The U. S. Patent Office will issue patents to the Westinghouse Electric & Manufacturing Company, of Pittsburgh, for "Hipernik," a new metal possessing unusual magnetic properties. This strange-sounding, synthetic name is made up of the first syllable of the two words "high permeability," the valuable property the metal possesses, and three letters from the word "nickel," which is one of its important elements.

"Hipernik" is the most magnetic metal ever discovered, being 160,000 times as magnetic as air. It is over thirty times as magnetic as ordinary open hearth steel or iron, which have a maximum magnetic permeability under 5,000, as the scientists express it.

Many of the uses to which the new metal may be applied are still under the observation of research engineers. Its use has greatly improved radio receivers and sound amplifying systems. Instrument transformers, too, have been made smaller and are more efficient and accurate when the transformer core is made of "Hipernik."

For many years experimental work has been carried on by Dr. T. D. Yensen, manager of the Magnetic Division of Westinghouse's Research Laboratories. But the experimental production was on a small scale and very costly, so arrangements were made to produce it on a commercial basis at The American Rolling Mill Company, of Middletown, O. "Hipernik" is now being rolled from 12,000 pound ingots, into coils many feet in length, on Armco's continuous sheet mills. The finished product is used either in sheet form or as cold rolled strip .014 inch in thickness.

To a world which daily leans more heavily upon electricity as its silent servant, the perfection of this improved magnetic metal will doubtless lead to many revolutionary developments.

ANNOUNCEMENT OF BRISTOL'S PNEUMATIC CYCLE CONTROLLERS

In the automatic control of process cycles the maximum of simplicity at a minimum of cost may generally be obtained by the use of diaphragm-operated valves actuated by a pneumatic cycle controller. A very large proportion of controlled processes are such that the sequence of the several events which terminate the cycle is the reverse of their order at the beginning of the cycle. Where this condition holds, the operations may be controlled by a single-cam instrument, in which a number of pilot valves are actuated in turn by a motor-driven cam. This cam may be made adjustable within certain limits; and speeds are determined by change-gearing between the synchronous motor and the cam-shaft. The starting and stopping of the motor are usually governed by a pressure-operated switch within the case of the instrument.

Where utmost flexibility is required, and the different events in the cycle overlap by varying degrees, rendering control by a single cam impracticable, there is another type of instrument available. Several individual cams are mounted on a common shaft, and each is adjustable through a wide range, both as regards the duration of its influence in the cycle and its position in the sequence of events. The pneumatic features of this instrument are identical with those of the single-cam controller; but, two pressure switches may be furnished, where it is desired to associate the starting and the stopping of the motor with different events in the cycle.

The instruments described do not perform the function of regulation; but they may be used in conjunction with any of a variety of pneumatic or electrical regulating devices for pressure, temperature, etc., and, with suitable accessory equipment, they readily lend themselves to those types of control where a certain degree of interlocking is required.

Automatic cycle control finds a wide application in the processing of foods, in the manufacture of articles from rubber and plastics, in textile and paper mill practice, in the operation of presses and molds, and, in fact, in any industrial process where it is required that valves, or mechanisms which can be made subject to the control of valves, are required to be operated in a more or less definite sequence.

Wheeling Steel Corporation has placed an order with the Freyn Engineering Company for 10 Freyn-Design Electric Roll Heaters and 2 Automatic Heat Regulating Controls for use with the same. This equipment is to be used on the sheet mills being rebuilt at the Beech Bottom Works of this company. Tokuyama Sheet Steel Company of Tokuyama, Japan, have purchased two additional Freyn-Design Electric Roll Heaters for use in its sheet mills. In addition to this, the French and German associates of Freyn Engineering Company have sold 7 Freyn-Design Electric Roll Heaters in France and Germany during the last few months. This makes a total of 330 Freyn-Design Electric Roll Heaters in service in sheet mills.

OBITUARIES

Thomas L. Cannon, aged 47, for 25 years identified with the steel fabricating business as manager of the Carnegie, Rankin and Leetsdale, Pa., works of McClintic-Marshall Company, Pittsburgh, now McClintic-Marshall Corporation, Bethlehem, Pa., died in Pittsburgh, June 11. At the time of his death he was Pittsburgh manager of the McClintic-Marshall Corporation. Mr. Cannon was graduated from Lehigh University and spent one year with the Gerber Engineering Company, Bethlehem, before becoming associated with McClintic-Marshall.

John A. Howard, aged 59, for many years chief engineer of American Radiator Company, Buffalo, died there last week.

Robert S. Carter, president of Latrobe Tool Company, Latrobe, Pa., died May 17. He also was president of J. M. Carpenter Tap & Die Company, Pawtucket, R. I. He was elected president of the Latrobe Tool Company in 1924, having previously been identified with Whitman & Barnes Manufacturing Company, Akron, O.

Samuel F. Kallenbaugh, 62, since 1928 sales manager of Morgan Engineering Co., Alliance, O., died May 8. He had been with the Morgan company more than 32 years, and for a few years prior to 1928 served as assistant sales manager.

These Representative Manufacturers Exhibited at the

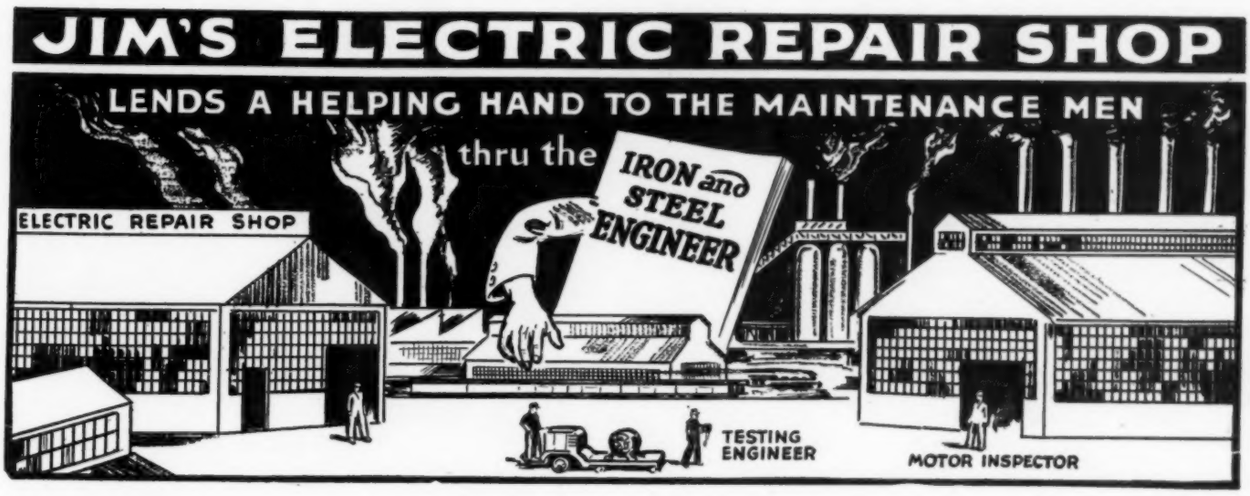
IRON AND STEEL EXPOSITION

CLEVELAND PUBLIC AUDITORIUM CLEVELAND, OHIO

JUNE 15 - 16 - 17 - 18 - 19, 1931

Exhibitor	Booth No.
Air Reduction Sales Co.	167
Ajax Electrothermic Corp.	120
Ajax Flexible Coupling Co.	103
Alliance Machine Co.	213
Allis-Chalmers Mfg. Co.	169–180
American Air Filter Co.	201–202
Anaconda Wire & Cable Co.	84
Appleton Electric Co.	143
Automatic Reclosing Circuit Breaker Co.	168
Babcock & Wilcox Co.	195
Bailey Meter Co.	130
Bantam Ball Bearing Co.	182
Bartlett Hayward Co.	121
Benjamin Electric Mfg. Co.	92–93
H. A. Brassert & Co.	61
Bristol Company	187–191
Brown Instrument Co.	181–183
Bull Dog Electric Products Co.	114
Burndy Engineering Co.	196
Carboloy Company, Inc.	47–48
Century Electric Co.	157
Clark Controller Co.	170-171-178-179-185-186
Cleveland Crane & Engineering Co.	128–136
Cleveland Rock Drill Co.	98
Cleveland Switchboard Co.	113
Cleveland Worm & Gear Co.	115
Colts Patent Fire Arms Mfg. Co.	129
Continental Diamond Fibre Co.	87
Crocker-Wheeler Electric Mfg. Co.	153
Crouse-Hinds Co.	214-220
Cutler-Hammer, Inc.	161-173-176-188
Davey Compressor Co., Inc.	98
M. H. Detrick Co.	131
Joseph Dixon Crucible Co.	83
John C. Dolph Co.	160
Edison Storage Battery Co.	112
Electric Controller & Mfg. Co.	199-200-206-207
Electric Machinery Mfg. Co.	233–234
Electric Service Supplies Co.	217
Electric Storage Battery Co.	172
Erie Malleable Iron Co.	80
Erie Steel Construction Co.	66-67-88-89
Fafnir Bearing Co.	85
Firth-Sterling Steel Co.	50
A. D. Fishel Co.	196
G. & W. Electric Specialty Co.	196
General Electric Co.	208-209-211-212-222-223-226-227
General Electric Lighting Institute	96
Great Western Fuse Co.	164
William Haddow Co.	52
Harnischfeger Corporation	190
R. B. Hayward Co.	44–45
Hodson Corporation	203
Holophane Co., Inc.	133
Homestead Valve Mfg. Co.	146
Horsburgh & Scott Co.	184
Hyatt Roller Bearing Co.	192–193
Ideal Commutator Dresser Co.	175
Insulation Mfg. Corp.	160
Interlocking Arch Co.	174
Iron & Steel Engineer	191
I-T-E Circuit Breaker Co.	107–108
Ivanhoe Division of Miller Co.	95
Johns-Manville Corp.	152–154
Keystone Lubricating Co.	110-111
Krout & Fite Mfg. Co.	160
Leeds & Northrup Co.	210

Exhibitor	Booth No.
Lewis Machine Co.	46
Limitorque Corporation	116
Lincoln Electric Co.	104-105-118-118x
Lincoln Engineering Co.	58–59
Lubrication Devices, Inc.	145–147
Ludlum Steel Co.	40
Maintenance Engineering	124
Manning, Maxwell & Moore, Inc.	163
Martindale Electric Co.	232
Master Wire Die Corp.	39
Micro Products Co.	29
Monitor Controller Co.	224
Morgan Construction Co.	36–37–38
Morgan Engineering Co.	155–165
Morganite Brush Co., Inc.	125
Morse Chain Co.	162
National Carbon Co.	132
New Departure Mfg. Co.	119
New England Butt Co.	42–43
Nichols-Lintern Co.	139
Norma-Hoffman Bearing Corp.	117
Northern Engineering Works	103
Ohio Electric Mfg. Co.	235
Okonite Company	135
Otis Elevator Co.	166
Parker Appliance Co.	138
Penn Machine Co.	126
Pennsylvania Lubricating Co.	194–198
Philadelphia Storage Battery Co.	82
William B. Pollock Co.	189
Pyle-National Co.	109
Reliance Electric & Engineering Co.	228-229-233-234
Roller Bearing Co. of America	81
Roller-Smith Company	122
Rollway Bearing Co., Inc.	156
Rotor Air Tool Co.	98
Rowan Controller Co.	221
Schweitzer & Conrad Co.	196
Sefton National Fibre Can Co.	49
Shallcross Control Systems Co.	159
S-K-F Industries, Inc.	127-137
Sleeper & Hartley, Inc.	33–34–35
Spraco, Incorporated	116
Square D Company	106
Standard Oil Co. of Ohio	197
Standard Transformer Co.	122
"Steel," Penton Publishing Co.	63
Steel & Tubes, Inc.	123
Texas Company	134
Thompson Electric Co.	97
Timken Roller Bearing Co.	144–148–158
Tool Steel Gear & Pinion Co.	149–150
Trabon Lubricating Equipment Co.	141–151
Trumbull Electric Mfg. Co.	101–102
Una Welding & Bonding Co.	60
Union Wire Die Corp.	32
United American Bosch Corp.	90
United Engineering & Foundry Co.	78–79
United States Graphite Co.	177
Vacuum Oil Company	65
Vianney Wire Die Works	52
Westinghouse Electric & Mfg. Co.	204-205-215-216-218-219-230-231
Westinghouse Lighting Institute	94
Weston Electrical Instrument Corp.	140
Edwin L. Wiegand Co.	225
Wire & Wire Products	31



Vacuum Impregnation of Lifting Magnets

By STEPHEN A. KISH*

Storm windows are used in homes to provide a dead air space between the windows and thereby preventing the warm air of the roof from radiating into the cold outside atmosphere. In like manner dead air spaces in a lifting magnet prevents the heat in the conductors from radiating to the atmosphere in which the magnet is operating, thus lowering its internal temperature.

By vacuum impregnation we are able to force an asphaltic gum into every crevice and pocket in the magnet's winding. We, thus change the dead air, heat retarding space into a heat radiating medium, which will carry the heat from the windings to the frame of the magnet, because the asphaltic gum is a heat radiating substance.

Vacuum impregnating the insulation in the magnet also prevents its drying and pulverizing during operation. When the internal insulation becomes dry it will absorb moisture, when the magnet cools. When the magnet is put into operation, this absorbed moisture will vaporize and penetrate further into the winding. Eventually a failure to ground will result or possibly short between turns.

Due to the severe service to which a magnet is subjected when used on a locomotive Crane, it has been found that after every lift the magnet is practically dropped 6 or 8 feet by simply releasing the brake. This jar soon loosens the winding and causes shifting of the windings and crushing of the insulation when the magnet is not impregnated. This shifting and crushing creates air pockets. When a magnet in this condition is set on the ground while out of service it will absorb moisture which possibly may cause a breakdown the next time power is applied.

We have noticed when an unimpregnated magnet comes to the repair shops for repairs, water is often found in the air pockets of the winding. Readings taken with a megger under these conditions the insulation will show an extremely low reading. When current is applied for several hours the insulation resistance value will increase immediately due to the drying out process. This shows that the moisture next to the frame is absorbed by the insulation farther in the winding when the unimpregnated magnet is dried out.

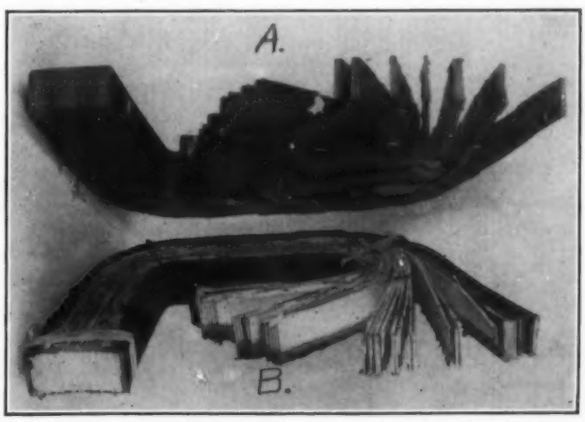


FIG. 1.—The section of field coil "A" shows how thoroughly the vacuum impregnation forced the gum into the insulation between the turns of the coil. Section of the field coil "B" which was dipped only in the gum shows by the white insulation between turns and dark only at the edge that it did not penetrate the coil.

We have dried out lifting magnets by applying power and then poured the hot gum into the magnets without using the vacuum impregnation process, but we found that the inside layers of the windings were never reached by this process. This is very efficiently illustrated in Fig. 1, which shows a comparison between "A" which is a section of a vacuum impregnated field coil and "B" which is a section of a field coil which had been dipped in a hot gum

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only. The white insulation of "B" is conclusive proof that the insulation has not been touched by the compound in this haphazard method of treatment of the insulation. We are using this illustration because the turns in a lifting magnet are insulated from each other by asbestos tape between turns. This material when thoroughly treated is an excellent insulator, but when untreated will absorb water like a sponge.

Our method of impregnating these magnets is very simple and can be performed by the average repair shop with very little equipment. The repaired magnet is made air tight so that when the vacuum is applied it will draw the moisture and air out of the magnet and not draw the external air in thru the cracks. The magnet is then heated by applying power to the windings. While the magnet is hot a vacuum is applied for three hours. See Fig. 2. This vacuum pressure when applied to the magnet will draw out the moisture which is vaporized by heating the winding.

Asphaltic gum is heated to 175°. (This gum does not flow until it is over 100°C) while the magnet has been undergoing the vacuum treatment. Before starting the impregnation, valve No. 1 is closed so the vacuum pump will not draw the compound into the vacuum system. The hot compound is under 80 lbs. pressure in the tank during the impregnation process. Valve No. 2 is opened which permits the hot compound to be forced into the magnet. The hot compound is applied under pressure for one hour.

With this method of vacuum impregnation the magnet is absolutely dry before the compound is forced into it. The pressure under which the compound enters the magnet is such that it will drive it throughout the entire winding thoroughly impregnating every path with dense hard gum insulation which will eliminate all hot spots.

We formerly used the vacuum pump to extract the air from the magnet but we later found that an air siphon works just as well and eliminated the necessity of having a vacuum pump. This is quite an item in the cost of the necessary equipment required to perform this task.

Vacuum impregnation of magnets has greatly increased the life of the magnets, and enables us to obtain as long a life out of a repaired magnet as one which is purchased from the original manufacturer.

FIG. 2.—Youngstown Sheet & Tube Co. uses a very simple home made device for vacuum impregnating repaired magnets. The vacuum is obtained by an air siphon and the heated asphaltic gum is forced into the magnet with shop air pressure.

The Association of Iron & Steel Electrical Engineers Wishes to Extend Their Appreciation and Thanks to the

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Engineers and Executives and Manufacturers' Representatives Who Helped to Make the 1931 Convention and Exposition One of the Most Successful in Their History.